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THE STEREOSCOPE
IN
OPHTHALMOLOGY

DAVID W. WELLS, M.D., F.A.C.S.

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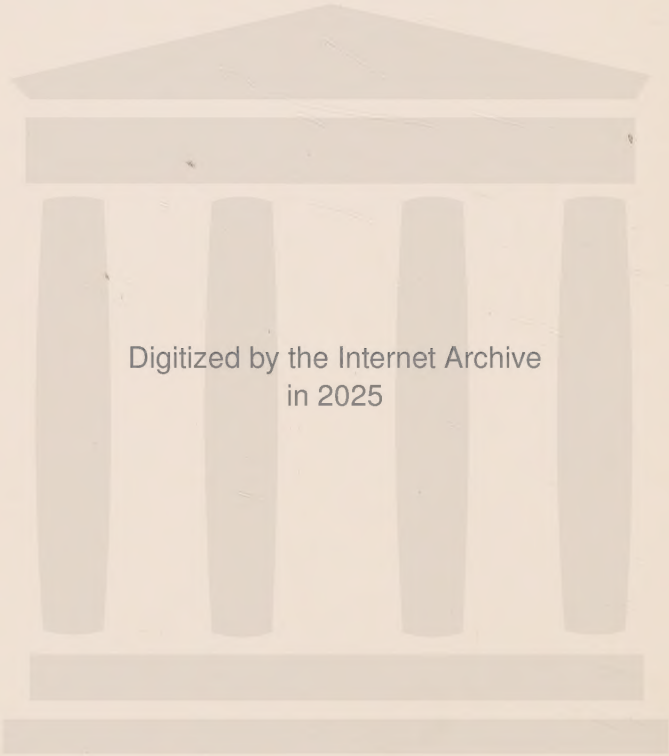
THE STEREOSCOPE IN OPHTHALMOLOGY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THE STEREOSCOPE IN OPHTHALMOLOGY

WITH SPECIAL REFERENCE TO THE

TREATMENT OF HETEROPHORIA AND HETEROTROPIA

DESIGNED TO ACCOMPANY THE PHORO-OPTOMETER STEREOSCOPE AND THE WELLS SELECTION OF STEREOSCOPIC CHARTS

BY

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Author of "Psychology Applied to Medicine"; "The Stereoscope": American Encyclopedia of Ophthalmology

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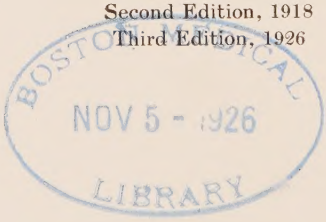

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PREFACE TO FIRST EDITION

Concerning the clinical importance of heterophoria ophthalmologists are not agreed. As a protest against the extravagant claims made by some enthusiasts, there has arisen a class of eminent practitioners whose members absolutely ignore the subject, and omit all tests for imbalance, unless there exists actual heterotropia. The author believes he occupies a middle ground, and that the opinions herein expressed are conservative.

The orthoptic treatment of heterotropia is not always successful, but there is a growing conviction that the surgeon who rests content with securing a cosmetic cure has not discharged his whole duty to his patient.

It is unfortunately still true that the majority of heterotropic cases are not seen by the ophthalmologist until the condition is quite firmly established. No opportunity should be lost to warn the family physician that the time to begin treatment is the minute the deviation is noticed.

Believing that the cases of heterophoria requiring relief are much more numerous than those of actual heterotropia, the greater part

of this essay will be devoted to the former condition.

For the benefit of the beginner in ophthalmology, a brief summary is given of the important points of binocular vision, the factors upon which orthophoria depends, the causes of heterophoria, and a discussion of the different methods of testing. While the treatment here presented is principally stereoscopic fusion training, other adjuvants are advised. The stereoscopic method is outlined with considerable detail, and is the result of several years' experience. It is earnestly hoped that many others may find in the phoro-optometer stereoscope, and the charts here described, that same degree of satisfaction which they afford to the author.

If the instructions seem more didactic than is consistent with good taste, he can only plead that he is attempting to lay before the reader his own method, and would gladly welcome any suggestions for improving it.

Believing that the limitations of the orthoptic treatment in heterotropia should be thoroughly understood, the indications for operative interference have been briefly stated.

D. W. W.

Hotel Westminster, Copley Square, Boston.
January, 1912.

PREFACE TO SECOND EDITION

Most of the changes in this edition are from suggestions of others who have taken up this work. One ophthalmologist, whom the author has not met, writes: "I think the best comment I can make of the present edition is to say that I have been able to master your system of muscle training to the point of having gotten some very good results, with no other instructor than the book itself." This is exactly what the author hoped to accomplish.

The author's modification of the Worth Advancement, having proven so extremely satisfactory, the mention previously made has been enlarged into a separate chapter, and although slightly foreign to the title of this book, may not be out of place, since post-operative fusion training is so extremely important.

Since the usefulness of the stereoscope has greatly increased by the appearance of the Haitz, Bissell and Lloyd charts, a chapter has been added, showing the adaptability of the phoro-optometer stereoscope for this purpose, reprinted through the courtesy of the American Journal of Ophthalmology.

D. W. W.

March, 1918.

PREFACE TO THIRD EDITION

The necessity of a third edition furnishes an opportunity for the introduction of the subject of Stereopsis, free use having been made of work of James, Howard and Cohen, to whom it is hoped full credit has been given.

The adoption by the author, and many others, of the Bausch & Lomb Wide Angle Stereoscope, the so-called Stereo Campimeter, calls for a few words regarding its use.

The chapter on Musculo-Capsular Advancement has been omitted, since it is slightly foreign to the main theme presented. It was published in the Journal of Ophthalmology, Otology and Laryngology, September 1914, reprints of which may be had on application.

Further experience has only emphasized the truth and importance of the subject here presented. The success of those who have really applied the treatment is a source of much satisfaction to the author.

D. W. W.

January, 1926.

FOREWORD

DISTINCTION BETWEEN DEGREE AND PRISM DIOPTER

THE author must protest against the very common mistake of confusing the terms Degree and Prism Diopter. A degree (°) is 1/360 of the arc of a circle, and should be restricted to Perimetry, the measurement of Heterotropia and Stereoscopic Campimetry. The unit of the prism diopter is a prism which deflects a ray of light 6 cm. at 6 m. Heterophoria is, therefore, measured in prism diopters.

According to Prentice's rule ("Ophthalmic Lenses and Prisms," 1917, p. 49), the prism diopter = tangent of 34′22″, figured as follows:

$$\begin{aligned} \text{Tangent } 1^{\Delta} &= .01 \\ \text{nearest smaller in table is Tangent } 0°30' &= .008727 \\ \text{difference} &= .001273 \end{aligned}$$

$$\begin{aligned} \text{nearest larger in table is Tangent } 0°40' &= .011636 \\ \text{nearest smaller in table is Tangent } 0°30' &= .008727 \\ \text{difference for } 10' &= .002909 \\ \text{difference for } 1' &= .0002909 \end{aligned}$$

dividing the whole difference by difference for 1′ = minutes to be added to 30′.

$$\frac{.001273}{.0002909} = 4.37' = 4'22''$$

$$\therefore \text{Tangent } 1^{\Delta} = 0°30' + 4'22'' = 34'22''$$

A 1° (degree) apex angle prism of glass, index 1.53, deflects a ray of light 31′48″ (Prentice: "Ophthalmic Lenses," 1900, p. 108), so that for the comparatively weak prisms required as spectacle lenses the two are practically the same, each deflecting a ray of light about 1/2° (degree). Using the prism diopter (Δ) as a unit, makes the fractional calculations extremely simple.

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CHAPTER I

BINOCULAR VISION — LAW OF CORRESPONDING POINTS — SEMI-DECUSSATION — FUSION FACULTY — STEREOPSIS — THE HOLMES STEREOSCOPE

Binocular single vision is a rather intricate psychic faculty, dependent on certain exact physical conditions. With each eye we see a separate object and, according to the law of corresponding points, it is necessary that the images of the object fall upon corresponding points of the two retinæ in order that single binocular vision may be realized. For central vision these points are the two maculæ, and for peripheral vision, these points must be equally to the right, to the left, above or below the two maculæ.

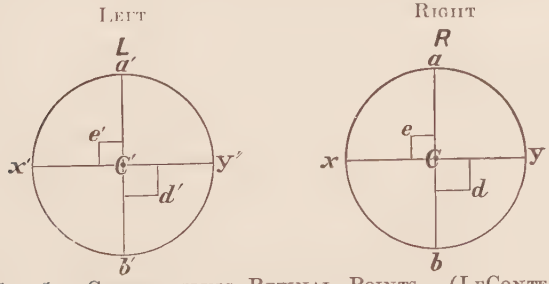

Fig. 1.— Corresponding Retinal Points. (LeConte.)

The field of binocular single vision is that portion of the two fields which can be seen by both eyes simultaneously, the projection of a single impression depending upon the semi-decussation of the fibres of the optic nerves, which occurs only in man and the higher apes. According to Duane's "best judgment," * "fibres arising from

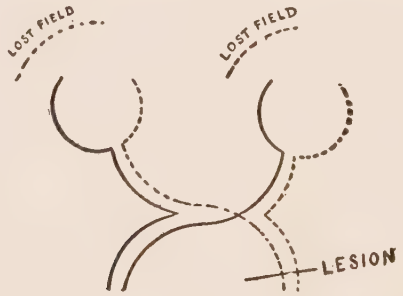

Fig. 2.— Semi-decussation of Optic Nerves.

any pair of corresponding points, meet at the chiasm, never unite but proceed brainward side by side and terminate in closely adjoined neurons in the occipital cortex." Semi-decussation makes possible the pathological phenomenon of hemianopsia, Fig, 2, and is the first physical essential of binocular vision.

A second physical requisite is the perfect coordination of the twelve extrinsic muscles, that

*Personal communication.

the eyes may be so directed to any point in the binocular field that the images shall fall on corresponding points.

When it is realized that a deviation of less than a millimeter* in the position of correspond-

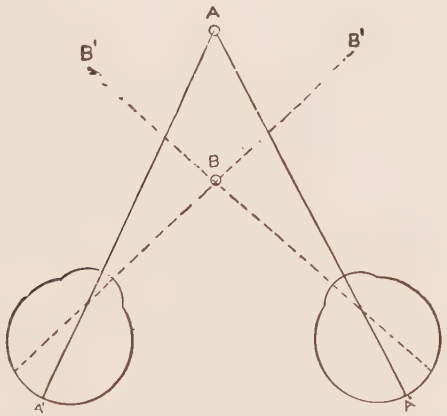

Fig. 3.— Physiological Diplopia of Objects Farther or Nearer than the Point Fixed.

ing points means diplopia for small objects, it is almost inconceivable that any mechanics alone could secure the desired result.

*According to Suter: "Refraction and Motility of the Eye," page 142. "The fovea centralis, upon which falls the image of every object attracting mental attention, does not exceed 0.4 mm. in diameter." Taking the distance of the nodal point in front of the retina to be 15 mm., Dennett, of New York, has shown by theorem of similar triangles, that, at a distance of one-half meter, an object to be discerned with normal acuity cannot exceed 13.5+ mm. in diameter.

THE FUSION FACULTY

According to Worth, sight in the newborn is limited to fixation of a light, so that all the finer qualities are the result of personal experience. The involuntary movements of the eyes of infants would show that there is no conception of binocular vision. The full development of the fusion faculty is not attained until the fifth or sixth year with the normal child.

Physiological diplopia means that objects nearer or farther than the point fixed are always seen double, but the adult has so far succeeded in ignoring this that it is sometimes difficult to make him realize the doubling.

With eyes fixed on A, Fig. 3, retinal images fall on the maculæ and single vision results. The retinal images of B fall on eccentric points (not corresponding) B′ causing heteronomous diplopia, B″. To overcome this the eyes must be converged until B′ falls on A′, the macula, causing homonomous diplopia of A.

There can be little doubt that this fact plays a very important rôle in the child's experience, the fusing at different distances developing the idea of perspective. Omitting the few cases of congenital defect, strabismus, better called heterotropia, if we adopt the more recent nomencla-

ture, begins between the ages of one and four, a time during which the fusion faculty should be developing. The significance of this fact in the treatment of this condition has been so ably presented by Worth that the reader is referred to his classic treatise, "Squint."

The argument is here introduced to emphasize the fact that *the third essential to binocular single vision is the psychic one of the fusion faculty.* Without such an overruling guidance, the necessarily exact co-ordination is inconceivable.

The frequent clinical experience, that loss of sight of one eye is often followed by divergence, is an unanswerable argument for the importance of the fusion faculty in keeping eyes straight, and it plays quite as important a part in the production and the cure of those *tendencies* to turn, grouped under the name heterophoria.

THE THIRD DIMENSION

A person devoid of a fusion faculty, or with only one eye, learns by experience to calculate distance by rapidly fixing the eye on objects to one side, and thus establishes a parallax which enables him to measure the distance by a sort of muscle sense.

The inferiority of this sort of estimation of distance, compared with that possible to one with

a well developed binocular fusion sense, was well shown by Howard at the Mineola experiment station. He claimed that many accidents in landing were due to the aviators' deficiency in estimation of depth difference.

Just how valuable this faculty is to chauffeurs, engineers and street car motormen has never been critically determined. When the facts are known, it is quite possible that visual tests will not stop with measuring the acuity of each eye and testing the color sense, but that a certain standard of stereopsis will be required. A simple plan for the routine office measurement of stereopsis or depth difference, which requires only five minutes, will be given later.

In 1890, Prof. Wells, of the Massachusetts Institute of Technology, found that some students had great difficulty in comprehending the diagrams in solid geometry, and had stereoscopic charts made to overcome this deficiency. Several of these have been included in the author's selection of stereoscopic charts.

While a good fusion faculty is always a valuable possession, and in many walks of life absolutely essential, it is cheerfully admitted that one sees many patients totally lacking such a sense. These people use each eye separately and are not conscious of any loss, and have no asthenopia from inco-ordination.

Fusion faculty is also a matter of degree. Some patients are able to fuse concrete pictures by a rapid alternation of the two eyes, but have no conception of perspective. Other cases are able to fuse large concrete pictures and have some perspective. Simultaneous macular perception is essential to true binocular fusion.

THE STEREOSCOPE

The stereoscope is "an instrument for blending into one image two pictures of an object seen from slightly different points of view." This is exactly what binocular vision accomplishes. The distance between the eyes is the base line, and therefore, each eye sees the object from "a slightly different point of view," and the extrinsic muscles and the fusion faculty are the "instrument" which does the "blending." For a fairly complete historical sketch of the stereoscope one should consult the contribution by the Author in American Encyclopedia of Ophthalmology, page 12172.

The only stereoscope in common use is the American, or Holmes model, which is exactly the same as the Brewster, except that it dispenses with the box and has an adjustable card carrier. The standard type consists of a pair of +5.25 lenses, so extremely decentered as to

produce a prism of about 8^{Δ} base out before each eye. This deflects the rays from the corresponding points of the stereograph, so that a variable amount of convergence is needed to focus them on the maculæ.

If one is able to relax his convergence until there is a slight divergence, he can dispense with the stereoscope, but when looking at a near point we naturally converge. In the standard stereograph the distance between the corresponding points varies, in the background it is 79 to 80 mm. while in the foreground it is 78 to 79 mm. Thus, a relatively greater amount of convergence is required to fuse near points than far points, and this, together with the difference in angle of the two views, produces the appearance of relief. This is similar to what takes place in our perception of the outer world. The physiological diplopia, which exists for all objects, nearer or farther than the point fixed (see Fig. 3), is overcome by rapid fixing of the lines of sight on the nearer and farther points by more or less convergence.

It is recognized that this simple explanation of binocular vision is extremely incomplete. For a further discussion of the various problems involved, the reader is referred to the writings of Wheatstone, LeConte, Javal, Parinaud, Pren-

tice, Tscherning, and Duane. Of the many other appliances for testing and training binocular vision, the most useful are Worth's Amblyoscope and the Bishop Harman apparatus.

MEASUREMENT OF STEREOPSIS

The ocular estimation of the relative distance of two objects is the result of several psychic processes, some of which are possible to a person possessing but one eye. Of these, visibility, apparent size of objects known to be alike, and monocular parallax are the most important. The relative value of these different factors has been well stated by Eaton (Brit. Journ. Ophthal., vol. iii., 1919).

In 1899, Pulfrich (Zeiss) introduced stereoscopic instruments for measuring distance. In using these it was found that some did not possess the requisite stereoscopic ability, so that it was necessary to select the observers. As a result of his experiments, he announced that persons with normal eyes have a power of perception of depth with as small an angle as 10″.

In 1908, James published in the Lancet a description of an instrument which he called a distance stereoscope for measuring the angle of binocular parallax. He stated that he found it to correspond with the angle of visual acuity;

that is, if each eye possessed an acuity of 1′ the angle of binocular parallax was 1′, although he furnished no data of his experiments.

In 1919, Howard adopted a slight modification of the James apparatus and made exhaustive tests of aviators at the Medical Research Laboratory at Mineola. His experiments showed that an individual with normal eyes of equal acuity and orthophoria should be able to distinguish a depth difference of 1.5 cm. at 6 m. This is equivalent to a parallactic angle of 5.1″ for a pupillary distance of 60 mm. He was dealing with picked men, many of whom had an abnormal visual acuity, and with such the depth difference perception was wonderfully acute.

Howard has also experimented with semaphores of 13 cm. diameter at a distance of 100 m. This size was adopted as it represents the tangent of the visual angle of 1′ at 100 m. He examined a number of the same men whom he had tested at 6 m. and found the binocular parallactic angle practically the same. The office test at 6 m. is therefore a trustworthy measurement of field stereopsis. It had heretofore been assumed by the writer that with his graded perspective charts (Series E) and an ordinary stereoscope, it was quite easy to determine the stereoscopic acuity, but the 6 m. test certainly allows of a more exact grading of the faculty.

So far as known, our knowledge of the binocular parallactic angle is limited to the findings of these three observers. It would therefore seem desirable to secure the co-operation of a large number of ophthalmologists to make these tests and publish their results. To do this the first essential is an inexpensive workable apparatus, and the second is the adoption of certain standards so that the results may be comparable.

James and Howard used a box in which rods of 1 cm. diameter could be moved antero-posteriorly, noting the smallest difference in distance which the subject could recognize. James used white rods in a black box and Howard black rods in a white box. The tests were made at a distance of 6 m.

Both speak of the importance of securing equal and uniform illumination. The apparatus of Cohen (Archives Ophthal., March 1919) overcomes this objection, and would be quite inexpensive if there were sufficient demand to make them in quantity. Dr. Cohen very kindly furnished his apparatus to the writer, giving permission to make such changes as were found desirable. Figure 4 shows it so modified.

It consists of a sheet iron cylinder 30 cm. diameter and 40 cm. long, open at one end, mounted on a tripod. Originally it had four

lights arranged quadrilaterally, but this has been simplified by reducing the number to two, in horizontal plane. The miniature lamps are on

Fig. 4.— Instrument for Measuring Stereopsis.

the ends of tubes which pierce the back of the cylinder and have an antero-posterior adjustment of about 20 cm. The lights were covered

with a white translucent glass and showed evenly luminous circles of 28 mm. diameter. These were so arranged that block letters or colored glass might be used in front of them. As now used, they are covered with black plates having openings of 1 cm. One is fixed and the other plate is adjustable horizontally so as to make the separation equal to the subject's P. D. The whole affair is dead black, so that the observer sees only the two luminous discs. There is thus no possibility of utilizing any monocular parallax.*

The standard conditions suggested are as follows:

1. The apparatus shall be placed at 6 m. from observer.
2. The luminous discs shall be 1 cm. diameter.
3. Separation of discs equal to subject's P. D.

If these conditions are followed the results will be comparable with the experiments of James and Howard.

In using the instrument, the subject is asked to close his eyes and the depth difference arranged at 10 cm. If on opening the eyes this difference is quickly recognized, the process is repeated with a smaller difference until the sub-

*Routine Office Measurement of Stereopsis, Archives of Ophthalmology, January 1920. Reprints available.

ject makes a mistake or is unable to see any difference. A few trials will suffice to determine a difference which is correctly stated.

The writer finds that patients with good perspective as shown by stereoscopic cards have a depth difference of 3 to 4 cm. This corresponds to a parallactic angle of 10″ to 13″ with P. D. 60 mm. This bears no relation to the visual angle of 1′, and contrary to James' statement does not vary with visual acuity. It is undoubtedly better with orthophorics than with heterophorics.

No one ever records visual acuity in terms of the visual angle, but as 20/20 or 1. So it will be much more easily comprehended if we record the depth difference in cm.

For the last five years the stereopsis of all training cases has been measured at the beginning and end of the series of treatments. It was hoped to demonstrate the relation of stereopsis to the degree of fusion faculty as shown by near tests with the stereoscope, and to note if improvement in fusion faculty for near would show a corresponding improvement in stereopsis.

This improvement is very marked in case records. There are some inconsistencies, for example, — a patient who fails on E_6 and has a depth difference of 1 cm. These irregularities

are not more frequent than the inconsistencies with the cards themselves; it is not uncommon for a patient to fail on one or two of the easier cards of a series and yet see correctly the more difficult ones.

CHAPTER II

ORTHOPHORIA — HETEROPHORIA — STEVENS' PHOROMETER — SAVAGE'S MONOCULAR PHOROMETER — WELLS' HANDY PHOROMETER — PRENTICE-WILLIAMS' PRISMOMETER — SCREEN TEST — DUCTION — CAUSES OF HETEROPHORIA — SYMPTOMS OF HETEROPHORIA

ORTHOPHORIA — right tending — is the condition where both eyes tend to look at the same point at all distances. Those who believe in the disturbing influence of kataphoria and anaphoria would dissent from calling this a condition of perfect muscle balance. While orthophoria necessitates normal orbits, proper strength, insertion and nerve supply of muscles, it is also influenced by other factors. Sight requires accommodation for all distances, from 15 cm. to infinity, and fixation of the two eyes upon this spot. This is a most beautiful example of co-ordination, but is easily disturbed by an abnormality of accommodation, which may be in the ciliary muscle itself, or in a refractive error, which necessitates abnormal accommodation for its correction.

It therefore follows that muscle tests should

be made with the patient wearing his correcting glasses, and also without, so that the influence of the refractive error may be determined. As absolute perfection is not to be expected, it would be advisable to adopt a minimum error that might still allow the classification orthophoria.

Heterophoria — cross or wrong tending — is the condition of most of the human family, if sufficiently careful tests are made. It would therefore be desirable to adopt some standard that recognizes a minimum of error to warrant the term heterophoria.

Only the principal forms, esophoria, tendency in; exophoria, tendency out; and hyperphoria, tendency of one above the other, will be here considered. Cyclophoria, a twisting tendency; anaphoria, a tendency of both eyes above the normal level; kataphoria, a tendency of both eyes below the normal level, are conditions which the writer does not feel qualified to discuss, much less to treat stereoscopically.

METHODS OF TESTING

Stevens' phorometer is probably most universally used. Savage objects to this method, because both images are artificially displaced.

The Savage monocular phorometer consists of

a rotary prism and a displacing prism before the same eye. This, he says, prevents the eye which is in the primary position from participating. This may be done with the phoro-optometer.

The same result is obtained with the Wells'

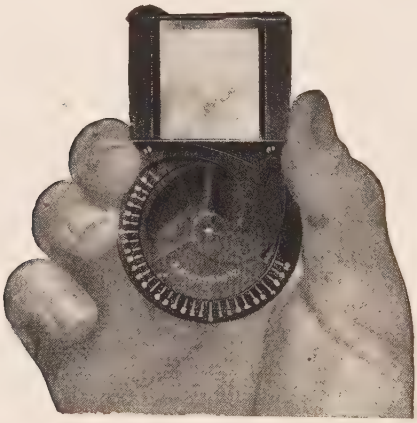

Fig. 5.— Wells' Handy Phorometer.

handy phorometer, which consists of a single ten-diopter prism and a weighted disc.

When the prism is tilted until the double images are horizontal or vertical the index on the disc indicates the amount and kind of heterophoria. This instrument is not intended to measure fractions of a prism diopter.

The Maddox rod is a very accurate test.

A test which diagnoses and measures the

error at the same time is one devised by Charles F. Prentice, of New York, in 1890.

It is based on the principle that a prism of 1^{Δ} causes a deviation of 1 cm. at 1 m., 5 cm. at 5 m., etc. It is, therefore, constructed for any distance, 5 or 6 m.

Fig. 6.— Prentice Phorometer.

The Wells apparatus, which has been in use since 1891, is copied from Prentice, and consists of lights 1 cm. diameter, 5 cm. between centers, on the wall 5 m. from the patient.

Vertical lights are green — horizontal lights red. Patient is armed with red glass before one eye of sufficient color to obscure the green, and green glass before the other eye of suffi-

cient depth color to obscure the red. If red glass is before right and green before left, right eye will see horizontal red lights and left eye vertical green lights.

If orthophoria exists, a perfect cross will be seen as if both the colors were seen by one eye. If exophoria, green lights will be displaced to the right, one spot for each prism diopter. If only two red lights are seen to the right of the green, patient has 4^{Δ} of exophoria. Red line seen on a level with the first green spot below the center indicates 1^{Δ} right hyperphoria. Williams, of Boston, modified this test by substituting luminous figures for the round spots, in order to eliminate the tendency to horizontalize and verticalize. The theoretical superiority of this test is that it obviates the necessity of distorting, blurring or displacing either retinal image.*

By all of these tests quite similar results should be obtained, but in one's record the particular tests employed should be indicated.

The cover or screen test is quite generally employed, and consists in alternately covering each eye with a card, while the patient fixes a distant light. The eye behind the card deviates

*The writer has fallen into the habit of calling this the chromatic test. It might be called the "red and green," or perhaps the Prentice-Williams', unless someone has prior claim.

if orthophoria does not exist, and recovers its fixation when the other eye is covered. Prisms held before one eye until all motion stops, measure the amount of the error.

This cover test differs from all of the others in that it is a strictly monocular test, and the influence of the fusion faculty is entirely eliminated. It is argued by the advocates of this method that it most truly reveals the real tendency.

In cases of high degree of heterophoria, or occasional heterotropia, the movement of each eye behind the screen should be observed — noting which recovers its fixation the more quickly on removing the screen. Obviously this is the favorite eye, and the one that lags will be the one that is suppressed in the tests of fusion to be given later.

The phoria at reading distance, 30 cm., should be tested by either the Stevens' or Wells' Phorometer.

DUCTION

Whether the case be one of orthophoria or heterophoria it is important to know the strength of the recti muscles, as many orthophoric patients have such weak muscles that they are unable to do continuous near work without asthenopia or nervous disturbance.

Normal accommodation means that each eye shall be able to focus an object as near as 8 to 10 cm. If the pupillary distance be 60 mm., convergence to this distance requires 60^{Δ}. If the average reading distance be taken as 30 cm., 20^{Δ} would be used.

As the comfortable maintenance of accommodation at 30 cm. requires an ability to accommodate at 10 cm., so the convergence faculty must be much greater than the amount habitually used.

Landolt* says, "We have tried to determine the quota of convergence, and our experience seems to demonstrate that this reserve amount ought to be about twice as great as the convergence required by the work."

Evidently the amount of reserve convergence necessary varies with the hours of application. It is certainly conservative to say that the actual power should be double that ordinarily used.

The convergence near point is measured by having patient fix a small light (ophthalmoscope lamp) held at 30 cm. and watching corneal reflections. The light is pushed nearer and nearer until one eye is seen to diverge. This should be as close as 5 cm. Diplopia may not be noticed but the objective feature is reliable.

*"Norris and Oliver System of Eye Diseases," Vol. IV, p. 133.

Duction is also measured by the power to overcome prisms and maintain single vision. Loose prisms from the trial case may be used until the limit is reached, but the rotary prism is more convenient.

Howe* has maintained that the accurate measurement of duction requires the use of prisms in reverse direction, beginning with one beyond the patient's ability to overcome, and working down to weaker, until the strongest which can be fused is found. This method was adopted by the A. M. A., 1907, as the standard, which, it would be understood, had been employed when cases were reported to the society.

The writer pleads guilty to having continued the old way, but admits that repeated trials often give quite different results showing increasing power.

Although there is no general agreement among the writers on this subject, it is probably conservative to consider 24^{Δ} as normal duction for the interni, 8^{Δ} for the externi.

CAUSES OF HETEROPHORIA

There are five generally accepted causes of heterophoria:

First. The malformation of cranium and orbits.

*"The Muscles of the Eye."

Second. Abnormal power, weakness or strength of one or more muscles.

Third. Tendons too long or too short.

Fourth. Insertions of tendons too far forward or back.

Fifth. Errors of refraction.

But it is the author's belief that a sixth cause, very generally overlooked, is *an incomplete development of the fusion faculty.* This does not mean that the patient possesses no fusion sense. Fusion faculty is a question of degree. Many true strabismics have a rudimentary fusion power. The great majority of people can fuse large stereoscopic pictures, but many fail conspicuously when viewing type of the size ordinarily used. If only a slight suppression of one is detected during the test, we must remember that the very conditions of the test force the patient's attention to the separate objects for the two eyes, and that under ordinary conditions suppression is probably much more habitual.

It is also important to discover the amplitude of fusion. Many patients who possess a high degree of fusion faculty with the stereoscope adapted exactly to their normal balance, show but little power to overcome the slightest obstacle. Such cases cannot maintain correct fusion under the varying conditions which the ordinary use of the eyes imposes.

The writer is aware that this is contrary to the teaching of Worth, "Squint," p. 168, that "heterophoria is essentially a motor anomaly, muscles too feebly or too powerfully innervated" and raises the question *upon what innervation depends?* The results of improving the fusion faculty given in the following pages, and especially the discussion of the Psychic Element and choice of cards, pp. 94 to 97, seem to the writer to prove that the fusion faculty has a great deal to do with "innervation," and is a *causative factor* in heterophoria as well as heterotropia.

SYMPTOMS OF HETEROPHORIA

Errors of refraction and heterophoria are so often coexistent that it is difficult to assign to each factor its distinctive symptoms.

Not until the refraction has been determined under a cycloplegic can one be certain in any given case that symptoms quite characteristic of heterophoria are not produced by the refractive error. Clinical experience in relieving a certain train of symptoms, which have persisted after correction of refraction, by treating the heterophoria, is the basis for the opinion here expressed.

In the order of importance the author would arrange the symptoms as follows:

Confusion. — No localized head pain, or pain may be referred to the suboccipital region or upper part of back. To the question, "In what part of the head is the disturbance?" the reply, "Oh, I don't know, all over," is so frequent that it is well-nigh pathognomonic. Inability to fix one's mind on study or reading is a frequent complaint.

Difficult Fixation. — If esophoria, of a distant object, like a public speaker. If exophoria, annoyance in conversation in trying to "look one in the eye."

Vertigo. — Of mild type, probably better expressed by the word confusion.

Drowsiness — after reading but a short time.

General Nervous Disturbance. — This is a very large and somewhat dangerous subject but it is certainly conservative to say that heterophoria is frequently a factor in migraine, "nervous dyspepsia" and epilepsy. How small an error may give rise to symptoms is a matter of idiosyncrasy. The same may be said of refractive errors.

For a further discussion of this subject, the reader is referred to Stevens, "Functional Nervous Diseases" (1884); Howe, "The Muscles of the Eye" (1907).

CHAPTER III

TREATMENT OF HETEROPHORIA — PRISMATIC GLASSES — OPERATIVE — MUSCLE TRAINING — STEREOSCOPIC TRAINING — PHORO-OPTOMETER STEREOSCOPE

TREATMENT OF HETEROPHORIA

Ordinarily the time for treatment is not until after the correction of the refractive error, as this alone may suffice to cure the heterophoria, and, as a general rule, with patients under thirty-five, not until the use of a cycloplegic has excluded latent refractive error. If the refractive error be slight, as compared with the heterophoria, one is justified in treating the heterophoria and ignoring the refractive error. If the treatment be by other means than the wearing of prisms, the patient is naturally quite pleased to be relieved without being condemned to wearing glasses.

METHODS OF TREATMENT

First. — The wearing of prismatic glasses, simple or combined with the refractive correction, the prisms so placed as to correct all or part of the heterophoria. This is often quite

satisfactory in the low degrees, and may even reduce the error, but it usually has the opposite effect.

This increase is believed by many to be the simple uncovering of a latent tendency. In esophoria the liability to increase is greater, so that one may regret the procedure.

The use of prisms in the reverse position, to stimulate the defective muscle, has been advocated by some. The author's few attempts to follow this suggestion have not been sufficiently promising to warrant continuance.

Second. — Tenotomies and Advancements.

In the higher degrees (more than 20^{Δ} of exophoria or 10^{Δ} of esophoria) surgical interference is justified. For the indications the reader is referred to the advice of Jackson in "Wood's System of Ophthalmic Operations."

Although the writer has a number of successful tenotomies to his credit, the result in esophoria and exophoria has, on the whole, been unsatisfactory — usually insufficient. For extreme degrees of exophoria 20^{Δ}-25^{Δ}, advancement of the weak muscle gives good results. (The author is strongly in favor of advancement over tenotomy in all cases of heterotropia.) *Certain it is that all surgery should be deferred until fusion and muscle training have been thoroughly tried.*

Third. — Muscle Training.

This has been principally for exophoria. Gould arms the patient with a pair of prisms, bases out, 10^{Δ} stronger than he can fuse at 6 meters. Eyes are closed, and on opening he fixes a candle held 10 to 20 inches away. The accommodation assists the convergence and two lights are fused. Candle is carried to opposite side of room, while patient holds images fused. This process is repeated with increased strength of prisms until diplopia results.

Loose Prisms. — It has been a very common practice to supply the patient with half a dozen loose prisms from 3^{Δ} to 35^{Δ}, so that by combinations he can use an amount gradually increased 3^{Δ}. With these held before the eyes he fuses the two images of a candle across the room.

After noticing several patients allow an eye to deviate outward, suppress its image, and then declare they saw one, the writer decided that loose prisms could be used safely only under the eyes of the oculist.

Peter, of Philadelphia, says this tendency can be prevented by occasional office visits.

STEREOSCOPIC TRAINING

The application of the stereoscope in the orthoptic treatment of strabismus — pre and

post-operative — is explained in Landolt's "Refraction and Accommodation of the Eye," 1886.

He used the Brewster box stereoscope 166 mm. long with +6.00 lenses, the patient wearing his full correcting glasses, so that the pictures

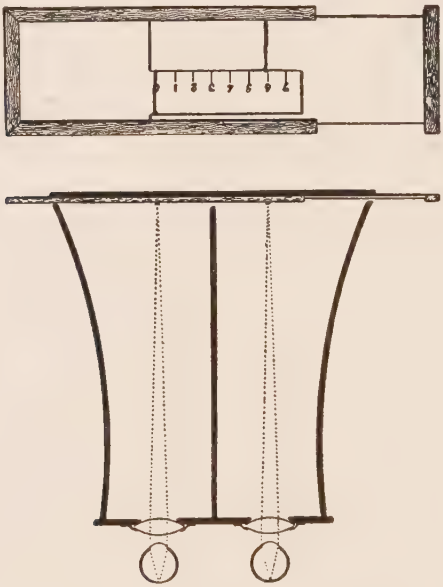

Fig. 7.— Landolt Stereoscope.

would be in focus without any effort of accommodation. His exercise object consisted of two cards, one sliding in front of the other; on one a vertical line above the horizontal, on the other a vertical below, the position where the line be-

came continuous showing the patient's fusion convergence. When this is found, the cards are adjusted towards the position for orthophoria and the patient strives to bring them together.

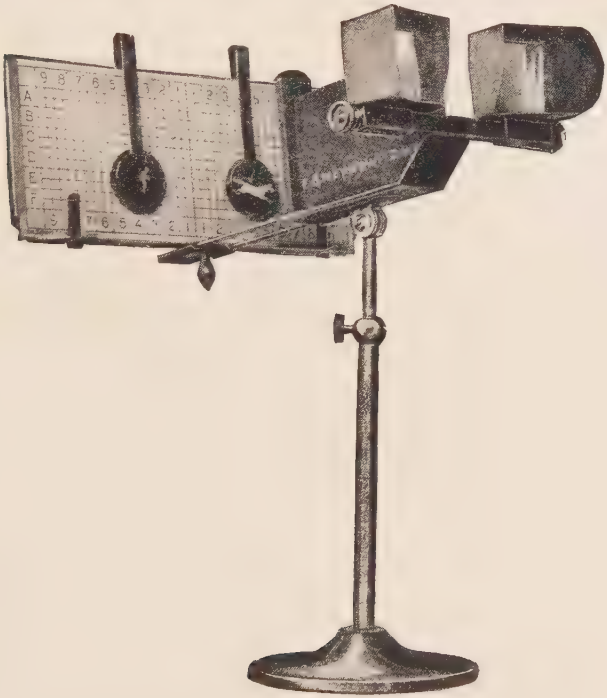

Fig. 8.— Derby Stereoscope.

Later, Richard Derby used a stereoscope mounted on a stand with object carriers which could be moved by an endless screw either vertically or horizontally.

In 1901 Worth brought out the Amblyoscope, adjusting mirrors to Priestley Smith's tubes, and hinging the tubes. With this amblyoscope it is possible to cultivate fusion in esotropia and exotropia. In treating these cases it is invaluable. It can be used also in the phorias.

The Bishop Harmon instrument (Fig. 11) is

Fig. 9.— Priestley Smith Tubes.

a useful means of demonstrating to the patient his lack of stereoscopic vision and is used by some as a means of cultivating the same, but in the opinion of the author it is inferior for this purpose to the method about to be described.

In all these appliances the training is secured by *moving the objects.* The author's experience soon showed that patients would not follow well

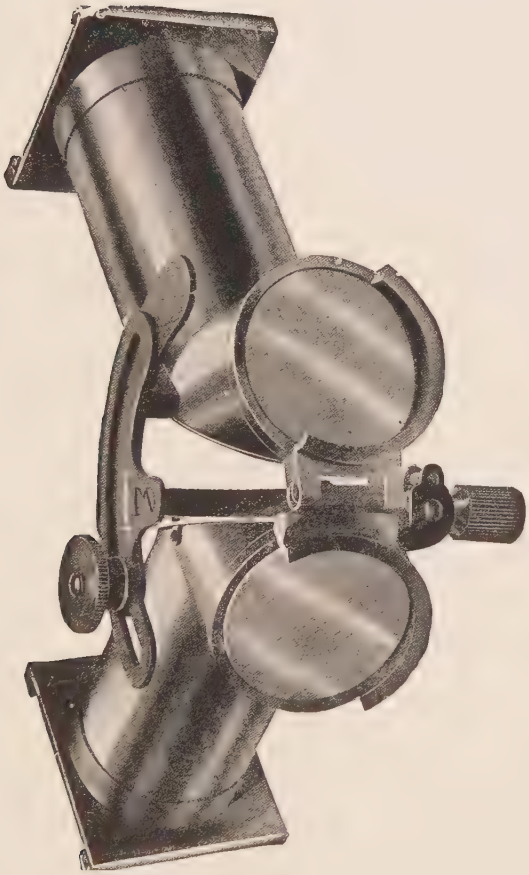

FIG. 10.— WORTH-BLACK AMBLYOSCOPE.

a moving object. The motion caused the fused image to break apart. This defect is probably less in the amblyoscope, as it is only the reflections of the objects which move. The fundamental principle of successful stereoscopic muscle training is the insinuation of the prismatic element by decentering strong spheres,

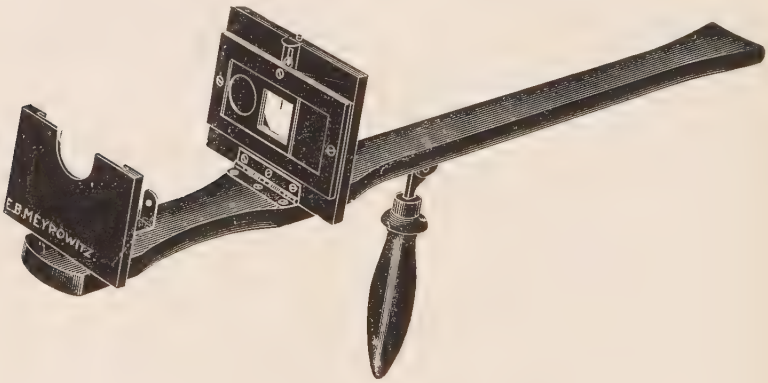

Fig. 11.— Bishop Harmon Instrument.

the objects remaining fixed. This point cannot be over-emphasized and will be referred to again and again. It is because of the smooth motion of the decentering screw for pupillary adjustment that the phoro-optometer is so well adapted for training.

In 1896 Javal published his great work "Manuel du Strabisme." He seems to have been the first to adapt the principle of the

stereoscope to "latent strabismus," or heterophoria, and to him the writer feels most indebted. It was his stereoscope with five adjustments that suggested the utilizing of the phoro-optometer for the same purpose. It seems incredible that a work of such great merit should not have appeared in English.

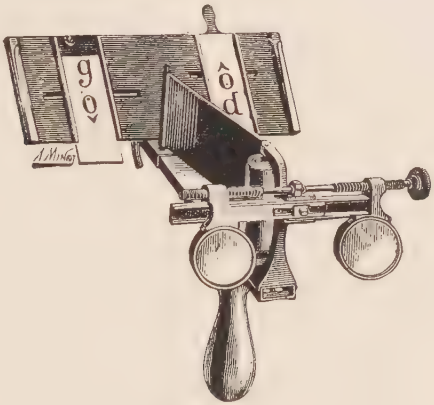

FIG. 12.— JAVAL STEREOSCOPE.

His charts, graded from easy to difficult, opened up an entirely new and practical field in fusion training. Most of the other charts, like Kroll's, Dahlfeld's and Hale's, were adapted to secure only the rudiments of binocular vision.

Much good work can doubtless be done with an ordinary stereoscope, but in order to carry out the author's methods one must have a phoro-

optometer, with two rotary prisms and the stereoscopic attachment. The phoro-optometer had been in constant use several years before its adaptability as a training stereoscope was discovered.

The first apparatus was made with an adjustable focus so that spheres from +5.00 to +10.00

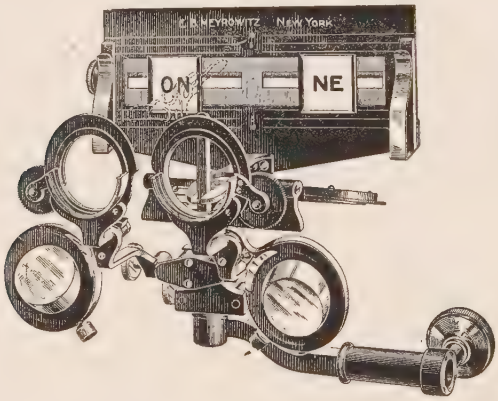

Fig. 13.— Wells Phoro-Optometer Stereoscope with Adjustable Object Carriers.

could be used. This was later discarded and a permanent distance of 10 cm. adopted. With this +10. spheres are always in focus.

Following the Derby model, adjustable object carriers were provided, with somewhat elaborate mechanism for vertical adjustment and an endless screw for approximating and separating them. This was essential to secure a gradual

and smooth movement, otherwise the eyes ceased to follow and fuse the two objects.

After using this arrangement some time, it

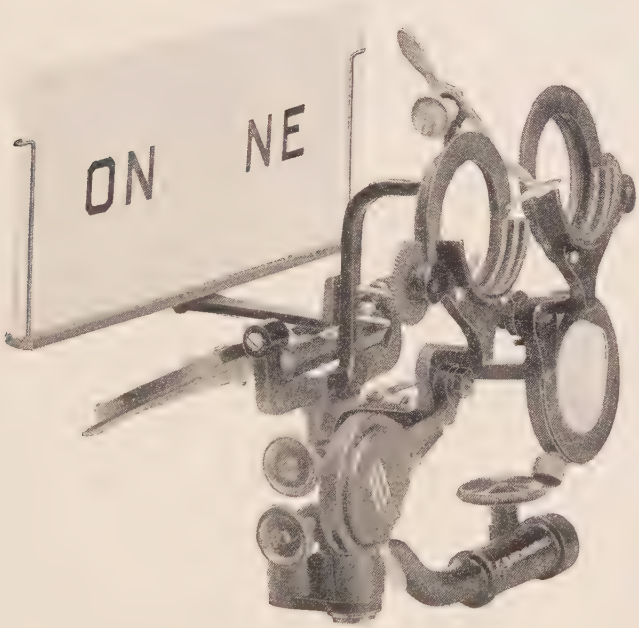

Fig. 14.— Wells New Phoro-Optometer Stereoscope Showing Simple Clips to Hold Cards.

was discovered that patients who found great difficulty in keeping the objects fused as the carriers were approximated, were much less disturbed if the spheres were separated by turning the screw for pupillary adjustment, and

that a much greater degree of prism could in this way be fused.

The 1902 model of the Wells stereoscopic attachment to the phoro-optometer, Fig. 13, shows the movable object carriers, but in the author's instrument they soon became fixed at 6 cm. apart.

It was later discovered that if one were a little careless in fixing the objects in the carriers, a slight tilting or vertical error interfered with fusing, so the object carriers fell into disuse and stereoscopic cards were used instead. The improved form is, therefore, simply the addition to the phoro-optometer of a clip to hold the cards. Fig. 14.

In 1904 the Wells selection of stereoscopic cards was published. This was a selection of the most useful from those previously brought out by Kroll, Dahlfeld, Hale and Javal. Only a few new cards were added by the author.

To the last (fourth) edition there is added the binocular test card, E_{10}, devised by Prof. Max Poser for the U. S. Government. The use of the Poser card alone as a test for true binocular vision is apt to be misleading, as many who fail to discern this perspective can be shown to possess third degree binocular vision by other cards of Series E.

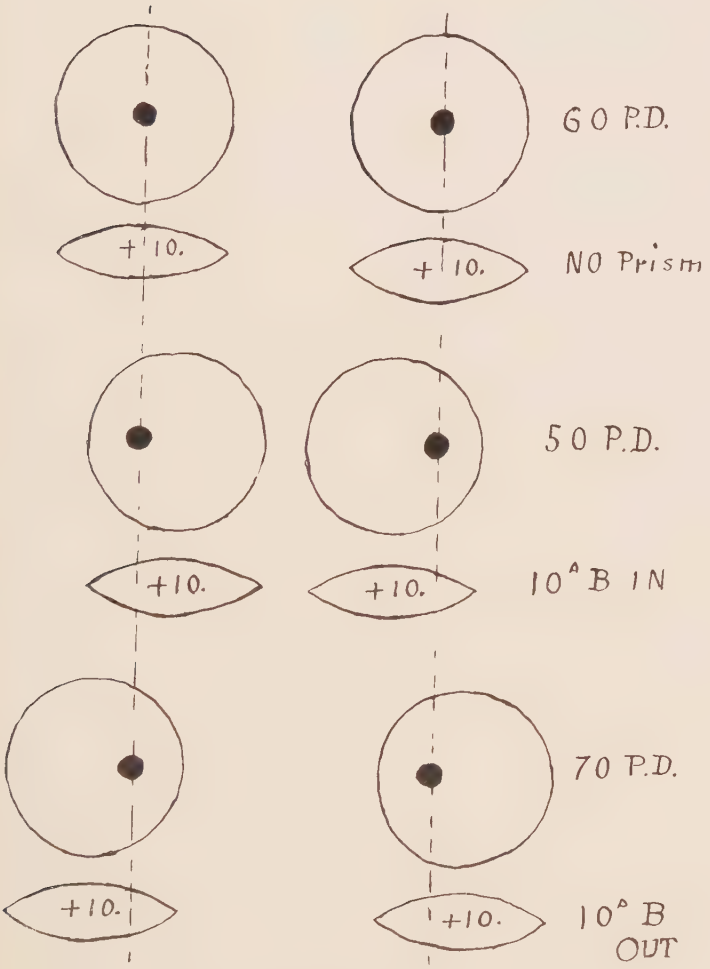

Fig. 15.

To guard against any misunderstanding the reader should bear in mind that in the instructions which follow, the letters and figures refer to the fourth edition.

DECENTERING SPHERES TO SECURE PRISM

The application of the principle of decentering of the spheres for the purpose of introducing extra prismatic effect, as applied to fusion training, is believed to be original with Javal,* but it has been greatly extended by the author, and its superiority over any other method known to him justifies a somewhat detailed description.

With o. u. +10., cards at 10 cm. are in focus. If the separation corresponds to that of the pupillary distance of the patient's eyes, no prismatic element is exhibited. If decentered 1 mm., 1^{Δ} approximately is produced. This +10. spheres make the calculation of the prism extremely simple. If the spheres are decentered *out* 5 mm., we have put before the patient 5^{Δ} of prism base *out*, just as truly as though a 5^{Δ} prism were inserted in the clip. If the spheres are decentered *in* 5 mm., 5^{Δ} base *in* is obtained. As the pupillary adjustment may be varied from 50 to 75 mm., it follows that 10^{Δ} or more may be utilized by this simple principle of decentration.

*"Manuel du Strabisme," p. 115.

The phoro-optometer enables one to adapt the stereoscopic principle to each patient's phoria, which is very important in cultivating fusion. Incidentally, it demonstrates how the patient's eyes tend to turn when used together for near. If the B_3 card shows any hyperphoria this is corrected with a prism from the trial case.

CHAPTER IV

STEREOSCOPIC TREATMENT OF EXOPHORIA AND CONVERGENCE INSUFFICIENCY — AUTHOR'S CARD FOR MEASUREMENT OF STEREOSCOPIC HETEROPHORIA — AMPLITUDE OF FUSION — RECOVERY EXERCISES — HOME EXERCISES — THE SUPPRESSED EYE — CONTROLLED READING: AUTHOR'S DEVICE — NUMBER OF CASES TREATED AND RESULTS

STEREOSCOPIC TREATMENT OF EXOPHORIA AND CONVERGENCE INSUFFICIENCY

Let us suppose a case of exophoria of 10^{Δ} distance, adduction subnormal, greater convergence faculty needed. With o. u. +10. in the

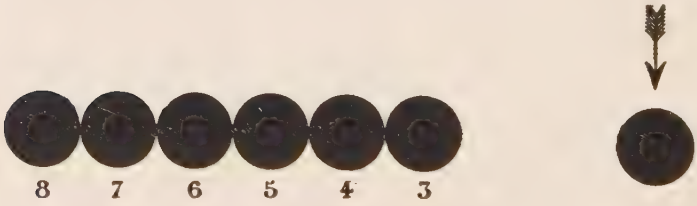

Fig. 16.— B_1. To Measure Fusion Convergence.

clips, centered to correspond to patient's pupillary distance, card marked B_1 is put in clip, and the patient is asked over which dot he sees the

Fig 17.—Showing the Lines of Sight When the Patient Sees the Arrow Over 5.

arrow. He will probably answer "five" or "between five and six." If five, this means that he has selected the number five spot, with which to fuse the arrow spot, therefore 5 cm. is the patient's easiest fusion distance with o. u. +10. Glasses correcting the refractive error should, of course, be worn and if there is much presbyopia, the o. u. +10. should be made enough stronger to correct it. This will slightly increase the prismatic effect of the decentering.

Eyes are closed and the two rotary prisms swung into position to give o. u. 5^{Δ} base out. Patient opens his eyes and again states position of arrow. If over six, the amount of prism which makes six centimeters the easiest fusion distance has been found. If not correct one or two trials will secure it. Should arrow be seen between six and seven, less than o. u. 5^{Δ} is required; should it be seen between five and six, more than o. u. 5^{Δ} is needed.

As all the cards, except series B, H and I are 6 cm. between centers, the stereoscope is now approximately suited to this particular patient, and we, therefore, proceed to test his fusion faculty. Unless the case be one of amblyopia, it is well to begin with series F.

With F_1, patient should see the vertical line passing through the dot. If the line, which is

seen by the left eye, is too far to the right, that is, heteronomous diplopia, the prism base *out* should be reduced until the direct alignment is secured. If the line be to the left of the dot, it is evident that the reverse is indicated.

By means of the card B_3 the exact prism needed may be determined. Obviously it is the

Fig. 18.— F_1.

amount with which the patient sees the lines intersect at six, but the cruder method with B_1 is preferable in the beginning.

B_3 is designed especially for the accurate measurement of stereoscopic hyperphoria, which is often quite different from that shown by other tests. The divisions of the red vertical line are 5 mm. apart. If the black horizontal line is seen to cross the red vertical line at H, 5^{Δ} right hyperphoria is exhibited. Hyperphoria may interfere with fusion. It is then necessary to correct

all or part of it with a vertical prism in the clip.

Patient's eyes are closed (unless otherwise stated, it is to be assumed that patient's eyes are always closed before each change) and succeeding numbers of F used in numerical order. It should be noted if either eye fails to see its respective lines and dots, and if suppression

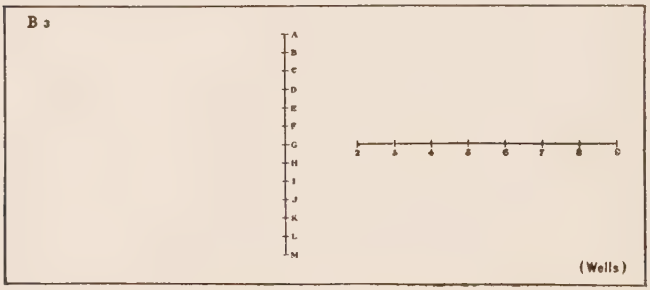

FIG. 19.— B_3. TO MEASURE STEREOSCOPIC HYPERPHORIA.

occur, whether it be always of the same eye or of alternate, right and left. Let us suppose that, beginning with F_4, the left eye fails to see the line or dots belonging to the left picture, although the letters are correctly read.

The case should be recorded:

"Stereoscope $+10. = 5$ cm., $\supset$ Pr. o. u. 5^{Δ} B out $= 6$ cm. Suppresses Left $F_{4, 5, 6, 7, 8}$."

This test might have been made with C_9 or series G, but it has been found that series F furnishes quicker and more reliable information.

Series E is devoted to perspective.

If with E_1, the antero-posterior relation of the dots is correctly stated, the subsequent numbers are tried in order. If E_5 is not correctly seen, to the record is added "E, o. k. to 5" or "Fails E_5."

Much attention is given to series E, both in the office treatment and the home exercises (mentioned later) to develop fusion with perspective, and one should not be satisfied until the whole series can be easily perceived, not only when the stereoscope is adjusted for the easiest fusion distance, but also when the prisms are increased so that much convergence is required. Many patients find E_{10} very difficult, so that it is not safe to conclude that a patient lacks good binocular fusion because he fails to see the perspective of E_{10}.

AMPLITUDE OF FUSION

C_7 is now put in place, and as the N's are just six centimeters between centers, the two N's are perfectly fused and the patient reads "O N E."

Now while the patient watches the fused image, the P. D. of the spheres is increased by gradually turning the screw to the limit (75 mm. P. D.)

Eyes are then closed and P. D. of spheres is reduced to minimum (55 mm.). 5^{Δ} more, making 20^{Δ} in all, is now turned up in each prism. Patient will fuse this easily — but let us note just what has been accomplished.

Assume P. D. = 60 mm., then he has fused 20^{Δ} less $5^{\Delta} = 15^{\Delta}$. As 10^{Δ} was required to bring

Fig. 20.— C_7. For Cultivating Stereoscopic Convergence.

the arrow over six on the B_1 card, 15^{Δ} less $10^{\Delta} = 5^{\Delta}$ = effort put forth. This process is repeated, adding from 5^{Δ} to 10^{Δ} each time, until the "ONE" breaks apart before the spheres are fully separated. If this occurs, using o. u. Pr. 25^{Δ}, when spheres show 65 mm. P. D., record should read "amplitude 'ONE' or $C_7 = 55^{\Delta}$."

It is extremely important at the outset to let the patient understand that you are giving him your undivided attention, and that the same is demanded of him. It is better to allow no third

person in the room, not even the assistant or secretary. The statement that this is really a test of one's will power, will put the patient on his mettle.

Much can be learned by watching the patient's eyes over the top of the phoro-optometer. Usually they both converge equally, but occasionally one eye will participate but little, and this will be usually the eye which is suppressed in the finer tests of fusion faculty. The treatment of this condition will be taken up later, but it is here noted to emphasize the importance of observing all the conditions.

In this particular, this form of stereoscope overcomes a serious objection to the amblyoscope, because with the latter the eyes cannot be watched, and we must depend on the patient's statements, which are naturally very unreliable, especially when treating children.

But to return to our case:

The limit of fusion would be anywhere from 20^{Δ} to 50^{Δ} on this first trial. Phoro-optometer is then removed and loose prisms held before the eyes base out, and strength increased until the limit for fusing a distant light is reached, the patient's eyes being constantly watched to guard against suppression without diplopia. The exercise should be stopped as soon as any fatigue

is evident and pneumo massage, fine Faradic electricity or high frequency given. The pneumo massage is quite agreeable to the patient. For some years high frequency vacuum tubes have been used, 50 milliamperes for five minutes. It may be that all this has no further importance than the soothing and suggestive effect.

This whole treatment requires 15 to 25 minutes, and is given three times a week for

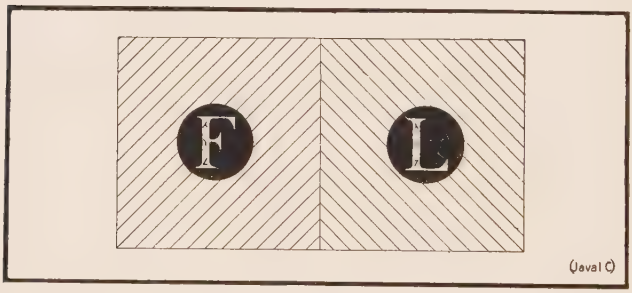

Fig. 21.— C_8.

three weeks, or until sufficient power has been attained. Most patients gain rapidly, but some show little improvement after half a dozen visits. After the 60^{Δ} of the two rotary prisms has been fused, round prisms from trial case are inserted in the clips. It is practicable to use as high as 15^{Δ} before each eye. This furnishes 90^{Δ} in all without any decentering.

Just what constitutes sufficient power is not

a fixed amount for all cases. Successful ones average 80$^{\Delta}$ to 90$^{\Delta}$ with the phoro-optometer stereoscope, and 50$^{\Delta}$ to 60$^{\Delta}$ loose prisms. Many, especially the younger, will develop an amplitude of over 100$^{\Delta}$, both with stereoscope and loose prisms. When sufficient power has been gained, time between treatments is gradually lengthened to two a week, one a week, one in two weeks, etc., provided the maximum reached at previous visit is still attainable.

It may be well to try the holding power of other cards, especially the L. F. the fusion of which makes E, but it is believed that the ONE gives the greatest mental stimulus, as one's sense of proportion is disturbed at seeing the letters break apart.

RECOVERY EXERCISE

The treatment is sometimes varied by what the writer calls the recovery exercise. With C_7 a few trials at decentering are made, and eyes allowed to close when the fusion limit is reached, and then the patient is told that this time his eyes are to remain open, that he must speak the instant he feels that he is about to lose his fused image, and that the prisms will be turned to help him get it clear again. It requires several trials before he can overcome the tendency to close

the eyes, and then the prisms will need to be reduced very much before he will say "all right, I have it now."

After six or eight trials the recovery will be very much quicker and will require only a slight reduction of prism. It is believed that this exercise has considerable practical value in teaching the patient to overcome the slight turning tendencies, which may annoy him in reading.

HOME EXERCISES

The patient is required to buy a stereoscope with clips for inserting extra prisms and a set of the Wells' stereoscopic charts. It is important that the patient own these, as he is expected to use them occasionally for some months, to insure his retaining his newly acquired faculty. These charts are not to be used indiscriminately, but in accordance with very exact instructions.

If at first examination the case showed a fair degree of fusion faculty, seeing half the cards in series F, G, and E, he is given F and G to use in numerical order, stopping when a few seconds fail to secure perfect fusion of the letters. This exercise requires ten to fifteen minutes and should be done three times a day.

After second visit, series E may be added to home work with instructions to run rapidly

through F and G. When these cards, which are 6 cm. between centers, are mastered fairly (not necessarily perfectly), series H and I are to be used in the following manner: Patient inserts B_1, notes position of arrow and selects the same number of series H or I to begin with. For example, if with B_1 arrow is seen over six, H_6

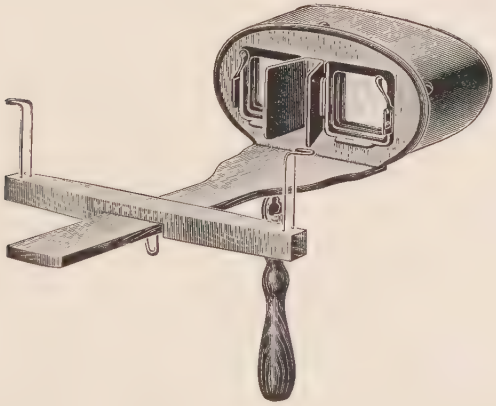

Fig. 22.— Holmes' Stereoscope with Clips for Extra Prisms.

is the first to be used. This will be fused with ease, as it is the distance between centers to which patient and stereoscope are adjusted. The order is now toward the smaller number, 5-1/2, 5, 4-1/2, etc., as it is convergence amplitude which is needed. When the narrowest of these cards can be easily fused, a pair of 5^{Δ} prisms is inserted in the clips, bases out, and the same exer-

cise repeated. Later 10^{Δ} prisms and occasionally 15^{Δ} are used.

This use of H and I must be explained to the patient with great care and he is given a card with the following printed instructions:

"Take card marked B_1. Notice the number of the disc over which the arrow is seen. Select same number of series H and I and work down to smaller numbers." On the same card the directions for all the home work are written; for example: "Series F, G, H and I, 10 to 15 minutes, three times a day."

In the average case ten to twelve treatments suffice to put the patient on an independent basis; that is, he has learned the knack, appreciates the relief of perfect fusion, and knows how to send the required neuricity to the internal recti.

Cross, of Worcester, Mass., has devised a cylinder with 14 facets, on which he has pasted the 13 cards of series H and B_1. This is mounted on the Holmes' stereoscope, arranged with a ratchet, so that the patient can turn up one after the other of the cards, progressing in either direction. Since it is wiser to have a period of relaxation between the repeated efforts of convergence, Cross suggests that patient's eyes should be closed while the cylinder is being revolved.

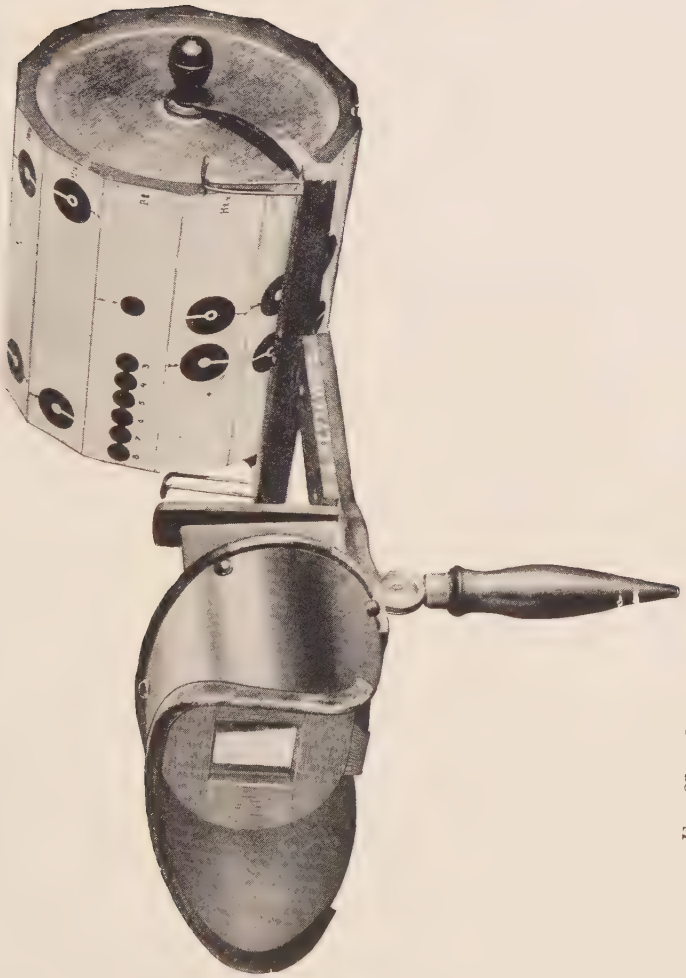

FIG. 23.— CROSS' STEREOSCOPIC ATTACHMENT FOR HOME EXERCISING.

Many years ago Landolt suggested the use of the ordinary stereoscopic pictures, putting two dots on one picture and a third dot on the other, so that the three will appear in a vertical line in the fused image.

For homework after the patient has ceased his regular visits, two or three dozen of such

FIG. 24.— SHOWING DOTS MARKED ON STEREOGRAPH.

photos, selected by him, are marked in this way, the dots being made as small as possible. He is thus taught to appreciate the absolute reproduction of natural scenery, and is constantly able to verify his binocular perception by a glance at the dots. These cards are used with the 5^{Δ} or 10^{Δ} prisms in the clips and thus combine fusion and convergence training.

It is advisable to insist upon good photographs

properly mounted. The Keystone Company, Meadville, Pa., offers a fine selection of views from all parts of the world.

CONTROLLED READING

Javal illustrates the control device of Bull, which is an affair somewhat resembling a stereo-

FIG. 25.—AUTHOR'S CONTROL DEVICE.

scope with an opaque bar midway between the eyes and a card placed in the clips. To overcome the possibility of a patient reading alternately with right and left, Javal constructed his "grill."

a little table with five vertical bars. This is placed, standing on four legs, on the page to be read.

After experimenting with various appliances, the author devised a control which enables the

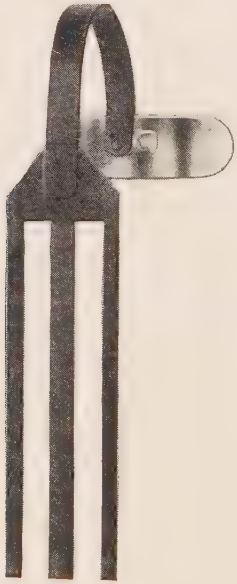

Fig. 26.— Triple Control Device.

principle to be applied to all of the patient's reading, writing and sewing. It consists of an ordinary head band, either leather, silk or the metal spring, but in place of the mirror an aluminum band is attached by the ball and socket joint.

This admits of considerable adjustment, which can be supplemented by bending the aluminum. The band is blackened to avoid reflections, and is placed half way between the face and the page. If either eye be suppressed a black band is seen across the page. This is shown to the patient by alternately covering the eyes. If patient does not occupy a conspicuous place, this control can be used for practically all near work, and this is insisted upon. At first there will be some complaint, but most patients soon come to appreciate the steadying effect and the ability to read with more comfort.

The latest model, Fig. 20, has three control bands and resembles an inverted trident.

The central band is 10 mm. wide, the lateral ones 7, and the spaces 13 mm. If this be held not more than 15 cm. in front of the eyes, the fields overlap sufficiently to allow of comfortable reading, but three times in each line the control principle is brought into play.

With a pupillary distance of 60 mm., the control at 15 cm., and the reading held at 35 cm. (14 inches), the overlapping is about 6 mm. Obviously this increases with the distance.

This triple control necessitates more exact adjustment than the single band, and may not be practicable for all near uses, but for quiet read-

ing, it prevents suppression as effectually as Javal's "grill."

The author is familiar with Gould's theory of dextro and sinistro-ocularity,* but feels obliged to differ from the opinion that any marked suppression of either eye is physiological. Undoubtedly many people, who habitually suppress one eye, may not suffer any annoyance from this condition. The same may be said of errors of refraction, but does anyone for that reason consider astigmia physiological? The writer maintains that the habitual use of the two eyes binocularly, with a minimum of suppression of either, is as ideal as is the emmetropic eye to uniocular-vision.

Therefore, every known means is utilized to overcome this suppression. If marked, it is admissible to atropinize the favorite eye. One of the less powerful cycloplegics is generally sufficient. A thin film of soap may be smeared on the stereoscopic lens, corresponding to the favorite eye. The whole object is to force the patient's use of the suppressed eye, by handicapping the favorite one.

*Ophthalmology, Oct., 1904.

NUMBER OF CASES TREATED AND RESULTS

In advocating a new method of treatment, it is realized that something must be said about results, but it is a somewhat difficult task to report accurately concerning therapeutic accomplishments.

Probably nine-tenths of those treated have been exophorics, so that of this class there have been a sufficient number to justify one in drawing some conclusions. From 1907 to 1912, 330 cases of this class were treated by the methods explained above. Of these about sixty per cent. gained a good convergence faculty varying from 60^{Δ} to 90^{Δ}, and the symptoms were relieved. Some of these became orthophoric by the various phorometer tests. Others still exhibit some exophoria, but much less than before. These are all classed as "cured." Fifteen per cent. developed equally good convergence, but symptoms were not relieved. Evidently symptoms were not caused by insufficiency. Fifteen per cent. more attained to 30^{Δ} or 40^{Δ} and secured partial relief.

About ten per cent. must be classed as failures. No improvement in muscle power could be secured. For some reason they did not respond. These last were not given a full course

of treatment. If marked improvement is not evident after five or six visits, the treatment is stopped.

Undoubtedly this list includes some cases of nervous instability, which a keener diagnostician would have referred to the neurologist. There have been some relapses, but the great majority of the "cured" cases have retained sufficient power for all practical purposes. Patients are admonished to test themselves, from time to time, with the stereoscope and cards, and if they notice any loss of power, to renew the home exercises.

Since this report was made more than a thousand cases have been treated with such satisfaction that a detailed review has not been thought necessary.

CHAPTER V

STEREOSCOPIC TREATMENT OF ESOPHORIA — MAY BE AN EXPRESSION OF CONVERGENCE INSUFFICIENCY — FUSION TRAINING SAME AS FOR EXOPHORIA — AMPLITUDE TRAINING THE REVERSE OR MAY BE SAME AS FOR EXOPHORIA

THE proper treatment of esophoria necessitates a careful estimation of all the factors concerned. One is not justified in concluding that the convergence faculty is too strong. Esophoria at distance is often associated with exophoria at near. In these cases duction will be found quite limited.

Paradoxical as it may seem, the writer is convinced that esophoria at a distance is not infrequently an expression of convergence insufficiency. Just how this is brought about he has no very definite opinion, but as the convergence function is the one most directly under the control of the will, it is conceivable that it might be exercised "not wisely, but too well," in a vain effort to overcome some annoying exophoria or hyperphoria.

Esophoria, dependent upon latent hyperopia, is quite common, and there is a consensus of opinion as to what this association implies. The constant need of innervation of the ciliary for distance, as well as near, in some way causes an overstimulus of the associated convergence — the co-ordination is disturbed. The full correction of the whole refractive error under atropine is, therefore, the first requirement and usually gives relief, but many of these cases show no reduction of the esophoria, the symptoms persist and the blurring of distant objects is quite annoying. For these cases and those not hyperopic, what shall be done? The use of prisms base out frequently "begets the calamitous necessity of keeping on." With each increase of prism more esophoria develops, until one may be forced to do a tenotomy or advancement to give his patient relief.

The stereoscopic treatment consists first of a thorough testing of the fusion faculty, and if any defect be found, the use of controlled reading (explained in Chapter IV) and the stereoscopic charts which cultivate a refinement of fusion, like F, G, E. To this point the treatment may be identical with that given for exophoria.

In using the phoro-optometer stereoscope, patient should learn to fuse with prism base in,

if we are to secure a greater divergence power. The same o. u. +10. are used in the frame, and card B_1 determines the easiest fusion distance by position of arrow. Let us suppose it to be seen over three, this means that the two discs 3 cm. apart are the easiest fusion distance.

Rotary prisms 15^{Δ} each base *out* ought theoretically to bring the arrow over 6. C_7 ON NE is then introduced and the spheres approximated so as to reduce the base out of the rotary prisms. When limit has been reached, patient's eyes are closed and the lenses separated as far as possible, and the base out of the rotaries reduced 5^{Δ}, leaving 10^{Δ} each.

If the patient's pupillary distance be 60 mm. and the phoro-optometer show 70 mm. P. D., 15^{Δ} each base *out* will be exhibited in this wide position and this will be as easily fused as at first. Now if the spheres be approximated while the patient holds the letters fused, when P. D. 60 has been reached, the prismatic element of the decentering has been eliminated, and the amount as shown by the revolving prisms, 10^{Δ} each, is the total. If the approximation be continued to 50 P. D., then the 5^{Δ} each base *in* produced by the decentering reduces the base *out* of the revolving prisms, and the patient has diverged from his first position and maintained fusion with o. u. 5^{Δ} base *out*.

Eyes are now closed again and the spheres separated as far as possible. Rotary prisms are now reduced 5^{Δ} each, so that the reading which was before 10^{Δ} is now 5^{Δ}. Patient opens his eyes and if he is able to fuse the ON NE, lenses are approximated as before. This process is repeated with smaller changes in amount of rotary prisms as it becomes evident that patient's limit is being reached.

As was said before, the home use of the cards as far as series G is the same with all forms of heterophoria, because with all of these cards the distance between centers is 6 cm., and their use is for the cultivation of a refinement of the fusion faculty. For amplitude training it is evident that the progression in the use of series H and series I must be reverse of that for exophoria; that is, if patient sees the arrow over 4 with B_1 card he should commence with H_4 or I_4 and work up to higher numbers, 5, 6, 7, etc.

In many cases where there has been present esophoria for distance and exophoria for near the convergence duction has been found so poorly developed that the writer has treated the case the same as for exophoria, both with the phoro-optometer stereoscope and the homework for cultivating amplitude.

Increased convergence has relieved the symp-

toms and has not increased the esophoria. In some instances orthophoria has been restored. It is experiences like these which have forced the conclusion that there exists a pseudo-esophoria, which should be interpreted as an insufficiency of convergence and not excess.

CHAPTER VI

TREATMENT OF HYPERPHORIA — STEREOSCOPIC TREATMENT NOT PRACTICABLE — PRISM-DUCTION TREATMENT — AUTHOR'S CARDS FOR RIGHT AND LEFT HYPERPHORIA

HYPERPHORIA

In a few cases stereoscopic treatment has been attempted with revolving prisms. The hyperphoria, as indicated by cards B_2 and B_3, is corrected by revolving prism. The ON NE card is introduced, and while the patient holds the image fused the prism correcting hyperphoria is reduced to zero, and as much reverse prism used as the patient will endure without losing the fused image. This is a kind of stereoscopic duction and can be repeated as many times as thought desirable. The results have not been sufficiently good to warrant its continuance.

In 1908 the writer devised two new series which were published as a supplement to the first edition of stereoscopic charts. These were designed for the treatment of hyperphoria. The characters ON NE were made of block let-

ters 8 mm. square, horizontal separation being 60 mm. in all. Each set consists of five cards. For right hyperphoria the right object NE is lowered 2, 4, 6, 8, 10 mm., corresponding to right hyperphoria of 2^{Δ}, 4^{Δ}, 6^{Δ}, 8^{Δ}, 10^{Δ}, if measured at 10 cm.

For left hyperphoria the left object ON is

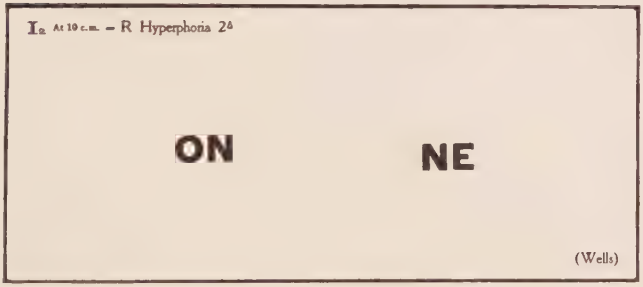

Fig. 27.— Discontinued Series.

lowered 2, 4, 6, 8, 10 mm., corresponding to left hyperphoria of 2^{Δ}, 4^{Δ}, 6^{Δ}, 8^{Δ}, 10^{Δ}, if measured at 10 cm.

The writer's idea was that if a patient with right hyperphoria of 8^{Δ} could fuse I_8* most easily, he should be able to progress to I_6, I_4, I_2, and thence to the ordinary cards with both sides horizontal. The results, however, were not satisfactory even when hyperphoria measured with B_4 in stereoscope at 10 cm. corresponded to

*This should not be confused with Series I of Fourth Edition.

hyperphoria measured at 5 M. Since no one with whom the writer had communicated had had better results with series I and J, they were omitted from the second edition.

A stereoscope might be constructed in which the spheres could be decentered vertically and

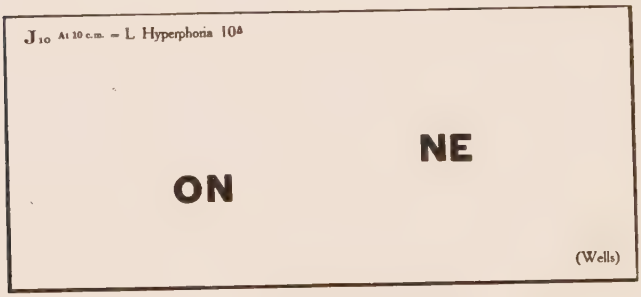

Fig. 28.— Discontinued Series.

the same principle applied as for training convergence and divergence, but of the result the writer is not particularly sanguine.

Hyperphoria frequently disappears as the convergence power increases, and if it remains in sufficient amount to give rise to symptoms, it is the author's practice to correct it with a prism, or if of high degree by tenotomy or advancement.

CHAPTER VII

STEREOSCOPIC TREATMENT OF HETEROTROPIA — OF CONCOMITANT ESOTROPIA — THE AMBLYOSCOPE — THE PERCENTAGE OF CURES — TREATMENT OF ALTERNATING ESOTROPIA — TREATMENT OF EXOTROPIA — THE TIME FOR OPERATION

Ever since Worth's first publication in the Lancet, May 11, 1901, the writer has been a conscientious follower of his methods. His suggestion of atropinizing or bandaging the fixing eye for months is certainly of great value, and although it had been previously practiced by Landolt and Javal, Worth did well in emphasizing it so forcibly.

A certain number of cases of concomitant esotropia can be cured by this method and the use of the amblyoscope, but this latter instrument has been rather disappointing. There are definite drawbacks to its practicability. In the first place, one cannot see the child's eyes and is, therefore, forced to depend on his statement as to what he sees. The imagination of the child is very vivid and no one who has tried to carry

out this treatment can have failed to be at his "wit's end" many times to know just what was taking place. Then it is absolutely essential that the case be seen early and that the parents' intelligent co-operation be secured.

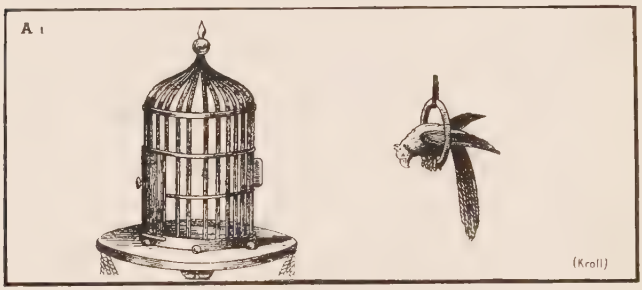

FIG. 29.— A_1. FOR LEFT ESOTROPIA.

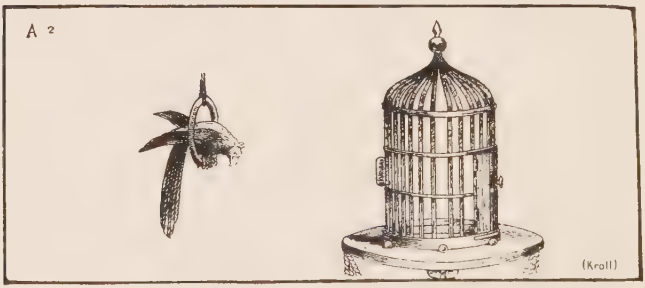

FIG. 30.— A_2. FOR RIGHT ESOTROPIA.

The wearing of full correcting glass in the fixing eye, and occasional atropine in the same, with some less than full correction of refraction for suppressed eye, will usually reduce the error one half. Little more than this can be done with

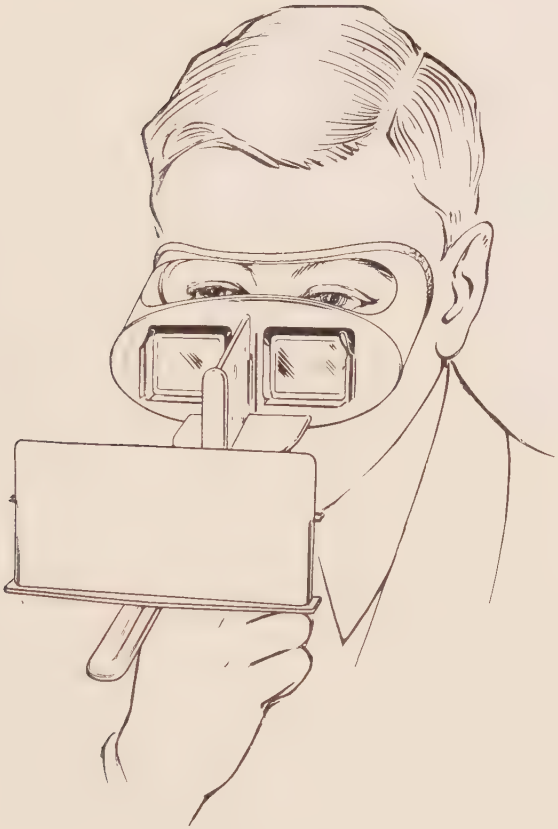

FIG. 31.— STEREOSCOPE WITH OPEN HOOD.

a very young child. As soon as possible Worth's marble test should be used to get a crude idea of visual acuity.

When the child is able to comprehend the

Worth amblyoscope, it is given with the simplest pictures for home use, and the phoro-optometer stereoscope used at the office. Fusion of low grade can often be secured with the latter in a case needing o. u. prism 30^{Δ} base out.

In order to better watch the child's eyes the hood of the stereoscope can be cut out at the top, leaving merely a rim to rest against the forehead.

Not until concrete pictures like C_1, C_2, C_3 can be fused need one expect much from stereoscopic exercises.

There is very little holding power in discrete pictures, either with the stereoscope or amblyoscope, — the bird out of the cage makes just as pleasing a picture as the bird in the cage, but when the head of C_2 loses an eye or an ear, one's sense of propriety is offended.

The prismatic element can be reduced by decentering, the same as in treating esophoria, and the eyes may be watched all the time over the top of the instrument to note their movements. In a favorable case the home stereoscope with as high as o. u. 15^{Δ} base out can be used, the amount being reduced as conditions warrant.

It is somewhat difficult to state exactly the percentage of cures that may be expected by orthoptic treatment alone. It is almost impos-

sible to carry out the full treatment with dispensary patients.

Of all the private cases of esotropia seen by the writer from 1913 to 1918, only twenty-five per cent. were less than six years old. Some of these moved away and were referred to colleagues in other cities. Others gave up the treatment after a few visits.

Excluding the congenital cases, nine per cent. were given the recognized orthoptic treatment, and of these one-half were cured and developed a fair degree of binocular vision. A few cases, averaging thirteen years of age, responded to glasses and fusion-training methods. Most of the other cases were corrected by advancement of one or both externi. Post-operative fusion training has been used in all except those lacking all fusion sense.

Since only twenty-five per cent. were less than six years old, it is evident that it is still necessary to emphasize the importance of beginning this treatment early. The intelligent co-operation of the family physician means that he shall refer every case to his ophthalmic surgeon, whenever there is discovered even an occasional squint. It is true that the wearing of glasses under two years is attended with some difficulty, but many other

expedients can be used to force the seeing with the turned eye. These may be atropine in the fixing eye and an occlusion bandage. The object of this very early treatment is to preserve the turned eye from amblyopia exanopsia, and to cultivate the fusion faculty during those years when it is developing in the normal child.

This treatment should be continued as long as the case shows improvement. This may be months or years, but it is certainly a mistake to delay operation too long. A rudiment of fusion can often be trained into a refined faculty if the eyes are put approximately straight by operation. This may be as early as five or six years of age, provided the operation be an advancement without a tenotomy.

ALTERNATING ESOTROPIA

In these cases vision is usually equal in the two eyes, and there is very little refractive error. A cycloplegic, or even a slight blurring of either eye, causes it to converge and the other eye to fix. Fusion faculty is usually nil, and any sort of orthoptic treatment generally of little use, but there are some exceptions where orthotropia and good fusion may be developed. It is, therefore, well to attempt orthoptic training in every case. Advancement of both external recti is

usually required, after which binocular vision of varying grade may be developed.

EXOTROPIA

If occasional, stereoscopic treatment and fusion training will usually cure the exotropia. The method is the same as for exophoria. The result is often orthophoria by phorometer, Maddox rod or chromatic test, but exophoria may be still shown by the screen test. As the normal condition of the individual is with both eyes participating, it seems appropriate to use a binocular test, especially the chromatic, in which the tendency to horizontalize and verticalize is reduced to a minimum. This also shows the value of the fusion faculty in maintaining orthophoria. If the exotropia exists all the time immediate advancement of the internal rectus, followed by stereoscopic training, is indicated.

CHAPTER VIII

POST-OPERATIVE FUSION TRAINING — THE DIFFICULT CASE — THEORIES — PSYCHIC ELEMENT — THE CHOICE OF CARDS — FUSION AMPLITUDE A VALUABLE RESERVE

Concerning post-operative training the latest word which we have seen from Landolt is as follows:

*"Immediately after the definite removal of the dressing, exercises for binocular vision must be begun. The patient operated upon for convergent strabismus will wear spectacles to correct the total hypermetropia and astigmatism, if it be present. The one who has been operated upon for divergent strabismus will be allowed, and even urged, to look at objects at close quarters, for the purpose of exercising his convergence. All patients should go through exercises intended, firstly, to perceive simultaneously the visual impressions of both eyes, then to combine the true impressions so as to give rise to the sensation of the third dimension."

While it is perfectly true that a majority of

*Bowman Lecture Trans. Ophthal. Soc. Vol. XXXI, 1911.

the previously strabismic eyes are extremely amblyopic, nevertheless to rest content with a cosmetic success, without attempting to cultivate binocular vision, is not discharging one's whole duty to one's patient. Even though the vision of one eye is quite defective, there may be developed a degree of fusion which is not only quite useful to the patient but is the best possible prevention of a recurrence of the heterotropia. Some with vision as low as .2 can be taught to appreciate relief, a true binocular single vision.

If a true antipathy to fusion exists, it is useless to persist. It is quite possible that such cases are due to a complete, instead of partial, decussation at the chiasm — a reversal to an ancestral type. Worth thinks the alternating cases fall into this category; but the rule is not invariable.

If the vision of both eyes is good, the change from heterotropia to heterophoria may induce all the symptoms of inco-ordination by the increased difficulty of suppression of one image. When one considers the complexity of the co-ordination required for binocular single vision, it is hardly conceivable that a surgical operation could change a heterotropia to orthophoria.

Illustrative case, No. 11819, April 4, 1916. Patient a lady æt. 28, with symptoms of head-

ache, feeling of strain in the head and neck for fifteen years; at present not able to read ten minutes without great discomfort.

From her former oculist the following history was obtained:

"Mrs. X's condition Feb. 24, 1915, was as follows:

R. V. 6/5. Cycloplegic: R. V. 6/6, with +.25 D. S. ⊃ +.25D Cyl. 90° = V 6/4.

L. V. 6/6. Cycloplegic: R. V. 6/10, with +.62 D. S. ⊃ +.50D Cyl. 90° = V 6/4.

"16$^{\Delta}$ exophoria distance, 20$^{\Delta}$ exophoria near, 3$^{\Delta}$ right hypophoria. A full correction was ordered for constant use, and various orthopic exercises tried, with no benefit to the heterophoria, and on April 20th I performed a Worth's advancement on the left internus with perfect immediate result. The exophoria gradually recurred, however, with the same intense asthenopia as before, and a complete tenotomy of the left externus was performed June 26th to correct an exophoria of 18$^{\Delta}$. This gave relief for about a month, when the symptoms began to recur. She was then given 5$^{\Delta}$ prisms over each internus, with 2$^{\Delta}$ prism base up right.

"Mrs. X has been a puzzling case, I must con-

fess, and I have come to the conclusion that her trouble lies in deficient fusion impulse. On more than one occasion since the second operation there was lateral orthophoria with the Maddox rod test, for a minute, the visual axes then gradually diverging until 10^{Δ} or 12^{Δ} prisms were necessary to fuse the images. There is a strong neurotic element, and she suffered inordinately both at the operation and afterwards."

Examination:

Under atropine

Right $+.25 \supset +1.12$ C 90° V = 1.
Left $+.50 \supset +1.12$ C 80° V = 1.

Exophoria 10^{Δ} Prentice Williams Color Phorometer.
Left Hyperphoria 2^{Δ} Prentice Williams Color Phorometer.
Adduction 16^{Δ}, Abduction 16^{Δ}.

Binocular vision tests:

Stereo +10 = 65 mm., Suppress L F_4, E_1 O. K.
"ONE" 30^{Δ} fuse 15^{Δ}, 2^{Δ} L Hyperphoria with B_3.

Since hyperphoria often disappears as the convergence increases, the vertical prism was omitted and she was given

Right —.25 ⌒ +1.00 C 90°
Left +.87 C 85°

Treatment:

For home work with stereoscope series C, F & G were used at first and patient came to office three times a week. After six visits she was given control device and told to begin reading a few minutes at a time. At this time the stereo-convergence with C_7 ON NE was only 40^{Δ}, showing slow progress. In fusing loose prisms the left eye would diverge without patient recognizing the diplopia, showing the importance of stereoscopic duction. At the eleventh visit orthophoria by binocular tests, but exophoria 9^{Δ} by cover test. Left hyperphoria $2\ 1/2^{\Delta}$, same as before treatment.

Stereo-convergence 90^{Δ} with C_7, loose prisms not tried, as the tendency to let one eye diverge was not cured. Could fuse H & I series with o. u. Pr. 5^{Δ} B out in stereoscope. As the hyperphoria persisted prism $1\ 1/2^{\Delta}$ base down was added to left.

Symptoms. — April 22nd, *i. e.,* two weeks after beginning treatment, "no pain in eyes, has read one-half an hour at a time." April 29th, "has used eyes most all day, doing exercises, reading and sewing."

As patient lived in a distant city, she was allowed to go home, but she was given very definite homework. The control device was changed from the single to the three prong, the 5^{Δ} prisms were increased to 10^{Δ}, and exercises varied by the use of a couple of dozen marked stereographs. Not seen again until September 6 (four months), when she reported that she could read two or three hours with the three prong control, and sew and write as long as she wanted to with the one prong control. Exercises had been kept up but at increasing intervals. Orthophoria by binocular tests, Exophoria 10^{Δ} by cover test. Stereoscopic convergence 90^{Δ} with C_7.

From the above case it is evident that post-operative training is carried out in the same manner as the pre-operative. If controlled reading is possible, the constant use of the device for all near work is most valuable. This should be continued for many months, possibly a year.

THE DIFFICULT CASE

It was stated in Chapter IV that the successful cases averaged ten to twelve treatments. Just when one should give up and call the case a failure is a matter of individualization. One patient, who had made practically no progress

in eleven treatments, at the twelfth visit seemed to "catch on," showing the cumulative effect of the previous effort, and in four more sittings fused over 100^{Δ} both with the stereoscope and loose prisms, with complete relief of symptoms. When seen again after six months there had been no loss of power.

If, as one watches the eyes over the stereoscope, and this should always be done, one eye is seen to turn but little, the prism before the other eye is turned to zero and the whole amount exhibited before this "lazy" one. This has never failed to stimulate the convergence. This will always be the eye which is suppressed in the test with series F & G.

Theoretically the accommodation should be at rest, and this is accomplished when the emmetropic eye looks through a +10. at a chart 10 cm. distant, but with a case which fails to converge when the spheres are separated, it is justifiable to utilize the accommodation to start the habit. This is done by substituting +7. or +8. spheres. One should also try the Gould exercise, which consists in putting in a trial frame, prisms base out, 10^{Δ} more than the patient can fuse. The eyes are closed while the prisms are adjusted. The room is darkened, and when the eyes are opened he sees a small electric light, like a candle,

about one foot away. This he fixes, as shown by the reflections in the middle of the pupils. The candle is then carried to the other side of the room. If the prisms are not too strong, the hold obtained by means of the convergence plus the accommodation is maintained and no diplopia results. The eyes are closed, and when again opened the candle is two feet away and is again carried across the room. The next time the candle is four feet away and the distance is doubled each time. If the candle can be fused when it is across the room when first seen, 5^{Δ} to 10^{Δ} more prisms are added and the exercise repeated. This is continued until diplopia results. Until one is sure the patient will not suppress one eye and thus fail to recognize the diplopia, it is well to have the assistant watch his eyes.

This exercise is to be used but a few times as it does not lead to any permanent gain in convergence, and often produces quite a strain, but it is justifiable as a means of starting a slow case. Another means of overcoming a persistent suppression of one eye with the stereoscope is to put a +12. sphere before the favorite eye. This blurs the picture before that eye and thus coaxes the use of the other. In the home exercises the patient smears a film of soap on the stereoscope lens before the favorite eye, just

enough to make the vision better with the suppressed eye.

THE PSYCHIC ELEMENT

Occasionally one will develop good stereoscopic convergence and show little power to overcome loose prisms. This can be overcome by having patient fix his finger held in line with the distant light. When prisms are held in place he will converge upon the finger. This latter is then moved away toward the light, and when at arm's length the attention is transferred to the light. After this is easily accomplished, he is told to imagine the finger is in position, and to fix attention upon it. He soon acquires the knack.

A highly developed fusion faculty, with good amplitude, is the ideal concomitant of perfectly corrected refraction. In correcting or relieving heterophoria, the first essential is the development of a refined fusion sense, if such does not exist, or in making habitual its employment in the psychic interpretation of two retinal images.

The power of a muscle depends not alone on its own physical properties, such as size, nutrition, place of attachment, etc., but also on the strength of the nervous stimulus which excites its action. In discussing this subject, in 1902,

the writer made the following statement: "The rapid development of adduction, which is so often obtained by this so-called 'gymnastics,' strongly suggests that the gain is not a muscle hypertrophy, but an increase in innervation, either in the responsiveness of the end organ in the muscle, or the convergence center, or both." All myology resolves itself into neurology and behind the nerve impulse is a fusion faculty.

In the educational treatment of tabes the incoordination is overcome by teaching the patient to gauge his motor impulses by the eye, in lieu of the normal sensory control. Repeated artificial contractions of the internal recti (the ciliaries remaining relaxed) establish a habit of increased action, so that they no longer lag when the impulse to converge and accommodate is felt. The co-ordinating faculty may also be taught to better appreciate the advantages of binocular perspective. This is no special pleading, but is analogous to other sensations. The pianist makes his fingers educate his brain, that the brain may do better work with the fingers. Tasks consciously performed are in time relegated to subconscious control.

If this interpretation of muscle gymnastics be accepted, it is evident that the first indication is to teach the patient the fascination of true bin-

ocular fusion. Just as in the ordinary prism exercises, with the eyes fixed on a distant point, the aversion to diplopia is an incentive to increased muscle action, so here the fused image becomes an anchor. With the eyes fastened on a fused image, made up of half pictures, one strongly resists an impulse which tends to pull it to pieces. The decentering of plus 10. lenses is a subtle means of insinuating such an influence.

In all exercises of this sort there is a psychic factor which should be utilized. Whether there is or is not a fusion center, there is a fusion faculty which can be cultivated, in proportion to the patient's attention and co-operation.

To do this, while the phoro-optometer stereoscope is being used, the patient should be repeatedly directed to fix his attention on the red N of the "ONE" card. To help him do this he should be told to analyze the color, to decide just what shade of red it is, or to fix his attention on the oblique line of the N. Other expedients will suggest themselves if the importance of this fixation of attention is appreciated. No distracting sounds should be tolerated; in fact, there should be no third party in the room.

The patient should also be aware that the oculist is thinking only of him, and whenever any gain, however slight, is evident, as one watches

the eyes over the stereoscope, some word of commendation should be volunteered. If no such commendation should be justified, he should be encouraged by the suggestion, "Now try a little harder this time."

Dr. Jackson says: "Orthoptic exercises are for nerve training — all forms of orthoptic apparatus depend for their usefulness upon a fusion sense, but whether this sense is strong or feeble, real exercise is possible only by getting the patient to make the effort," *and who is best qualified to do this?* Certainly not the assistant or the office nurse. *The man whom the patient has been led to consult is the one who can do the most for him.* The patient should receive his individual and undivided attention. There should be no third person in the room, and no distracting interruption. With the phoro-optometer stereoscope one is able to watch the patient's eyes while the lenses are being decentered, and if either eye is seen to fail to fix, the patient should be called up sharply with the words: "Careful, keep that left eye on the dot," etc. He will often express surprise that his lapse has been detected, and renew his effort to fix his attention. Besides he should be encouraged to try a little harder next time, and commended when it is evident that the effort is being

made, and he should have no doubt that *his success is a serious matter with the physician.* In short he should be given a-hypnotic suggestion for all it is worth.

THE CHOICE OF CARDS

The difference in the holding power of different cards has been mentioned. Formerly C_8 of Javal was used. This consists of separate letters L and F, the fusion of which gives E. After considerable experimenting the author devised the ON NE, the two N's printed in red, and believes this possesses the greatest holding power of anything yet produced. In the first place the word spells O N E, and when disjointed the ON NE is meaningless. More letters are superfluous and detract from fixation. That there is a subtle suggestion in this, one can easily verify in the following way: After the card ON NE has been used on several occasions, if the prism is arranged so patient sees arrow over 6 of the card B_1, and if then C_7 is dropped into the clip, the patient will often be confused, but will be immediately relieved if 5^{Δ} or 10^{Δ} more of prism be turned up. This shows that while conditions were exactly right for easy fusion of C_7, the instant that card appeared he immediately remembered what it had previously required and

involuntarily converged his eyes more than was necessary. It is advisable to experiment with other cards, especially if the case is not progressing well.

FUSION AMPLITUDE A VALUABLE RESERVE

In convergence insufficiency we are dealing with an inco-ordination of convergence and accommodation. The nerve impulse sufficient to secure accommodation is insufficient for convergence. To relieve this and to restore co-ordination, it is necessary to incite, associate and to make habitual a greater degree of convergence with a given amount of accommodation. For this reason it has always seemed to the writer that exercises which bring into play the accommodation as well as the convergence are illogical; *e. g.,* dot exercises at the reading distance or candle as used by Gould.

With eyes fixed on a distant light, it is assumed the accommodation is zero, but this is difficult to verify. When emmetropic eyes looking through +10. lenses see clearly at the focal distance, 10 cm., we have proof that accommodation is relaxed, and it is under these conditions that we secure a very abnormal amount of convergence. To a certain extent the same is true of the home use of the stereoscope with additional prisms in the clips.

With perhaps one-half of one's successful cases orthophoria will be secured, with the other half the heterophoria will be reduced, but the patient will have secured such a super-abundance of amplitude that he is able to overcome the wrong tendencies automatically without discomfort.

Not infrequently one sees a patient who has learned to overcome strong prisms who is still uncomfortable, because his fusion faculty is poor and co-ordination for small objects, like types, inexact. One can understand that a man might be able to make a long jump, and yet not able to land on an exact spot less than his full distance. This ability to land exactly is what perfect co-ordination requires. The stereoscopic training of convergence accomplishes just this exactness. Stereoscopic convergence reproduces the conditions required for perfect binocular single vision. Finally, this is best stimulated by the decentration of spherical lenses.

CHAPTER IX

THE ADAPTABILITY OF THE PHORO-OPTOMETER STEREOSCOPE FOR HAITZ AND BISSELL CHARTS — THE LLOYD COMBINATION CHART — THE STEREO-CAMPIMETER

THE ADAPTABILITY OF THE PHORO-OPTOMETER STEREOSCOPE FOR THE HAITZ, BISSELL AND LLOYD CHARTS

In using Haitz charts the writer at first followed Haitz's instructions,* using an ordinary Holmes stereoscope, marking on the same the distance at which chart should be viewed. It was soon found that holding the stereoscope was tiresome for the patient, and quite unsteady. As constant use is made of the phoro-optometer it was found much more satisfactory to make the stereoscope to order for each patient; o. u. +5.25 toric lenses are used with the chart at 19 cm. In the ordinary use of the phoro-optometer stereoscope o. u. +10. is employed with the cards at 10 cm. This makes each prism diopter ($^{\Delta}$) =

*Translation published by Author in the Journal of Ophthalmology, Otology and Laryngology, Dec. 1916. Reprints available.

deviation of 1 mm. With o. u. +5.00 at 20 cm., each prism diopter ($^{\Delta}$) = deviation of 2 mm. With the B_3 card the natural fusion distance is determined, and sufficient prism introduced to make lines cross at 8, since Haitz charts have a separation of 8 cm. For example: should the red line cross at 5 this means that 5 cm. is the natural fusion distance. To secure the crossing at 8, fifteen diopters more is required, since 30 mm. more deviation is needed, and at 20 cm. each prism diopter = 2 mm., $30 \div 2 = 15$. If the patient happens to converge, more prism will be needed, the exact amount being determined by turning the rotary prisms. The patient should wear his refractive correction.

The stereoscope is now ideal for mapping a central scotoma, and at the same time it has been demonstrated that the patient has binocular vision sufficient for the test. Since visual acuity is often poor and fusion faculty of low grade, it was found that the lines of the B_3 card were too fine to be easily seen by many patients. A modification of B_3 with heavier lines has, therefore, been drawn upon the back of the Haitz chart.

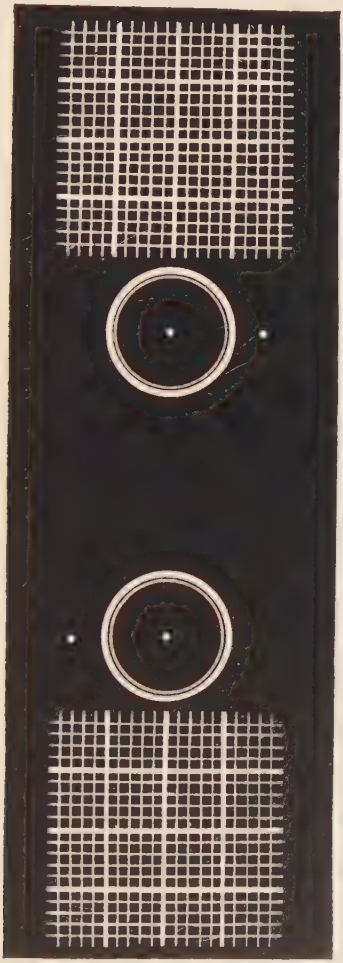

FIG. 32.— BISSELL CHART FOR MEASURING BLIND SPOT STEREOSCOPICALLY.

BISSELL BLIND SPOT CHART

In 1916 Dr. Bissell of Rochester, N. Y., published his chart for measuring the blind spot by the Haitz principle of stereoscopy.

In using this, it is necessary to get a wider field. This is easily obtained by commencing with the o. u. +5.25 decentered out 5 or 10 mm. wider than the patient's P. D. and substituting for the revolving prisms, after the necessary

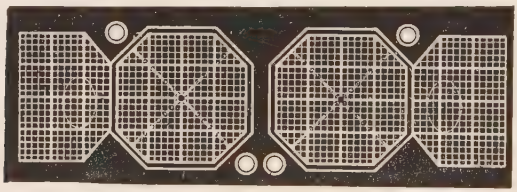

FIG. 33.— LLOYD SLATE.

amount has been determined, plain prisms from trial case. This increased distance of the lateral part of the chart changes the perfect correspondence of squares to degrees of the arc, but if one wishes to be more exact the chart can be bent by having a third support, so that the ends and the center will be the same distance away.

THE LLOYD COMBINATION CHART

Lloyd's slate, described in the Ophthalmic Record, August 1917, is a combination of the

Haitz and Bissell charts, and, therefore, suffices for both purposes.

THE STEREO-CAMPIMETER OR WIDE ANGLE STEREOSCOPE

While it is thoroughly practical to use the phoro-optometer stereoscope for measuring the blind spot, 10° vertically and 20° horizontally, it necessitates putting in a longer diaphragm and special lenses. Moreover the apparatus lacks stability.

Stereo Campimetry has become such an important branch of Ophthalmology, especially in the treatment of glaucoma that the Author has been for some years using the Bausch & Lomb instrument on a separate table with daylight lamp.

Since this is simply a wide angle Haitz, there is no new principle involved. It was put on the market without sufficient instructions in regard to the extra prisms, *assuming* that the patient would see stereoscopically. Since the lenses are already selected and the distance stated, the introduction of the Card B_3 will show immediately if the patient have binocular vision good enough for a stereoscopic test: he will see the lines cross. Since the centers of the chart are 8 cm. apart, this crossing should be at 8. If elsewhere the

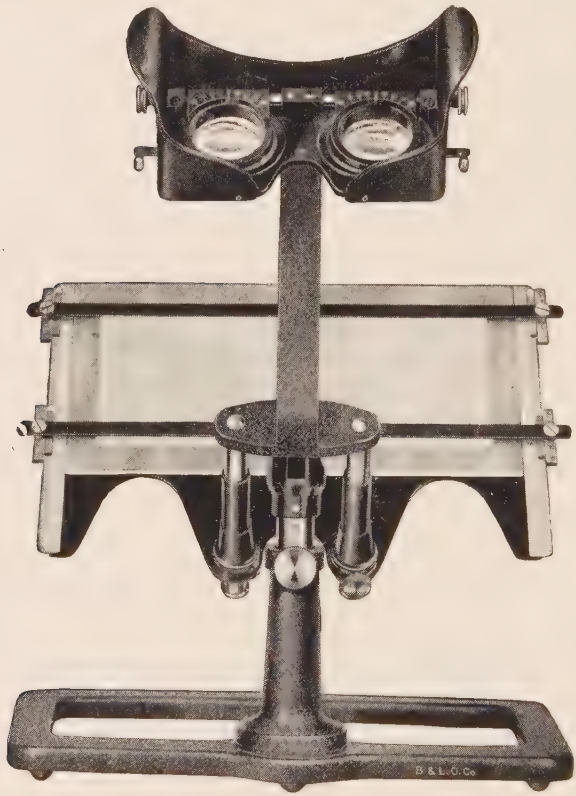

FIG. 34.— WIDE ANGLE STEREOSCOPE.

rules given on page 101 for the phoro-optometer stereoscope apply. The hyperphoria can be corrected by turning the appropriate adjusting screw.

Not until all this is done is the patient capable of correct binocular fixation.

If stereoscopic vision does not exist, the monocular field of the 20° circle can be taken quite as accurately and quickly as by any other method.

While the full form field is important it is this 20° field, with the enlarging blind spot, which furnishes the important evidence of the progress of glaucoma.

Instead of using the slate it is much more expeditious to have the assistant stand behind the patient, chart in hand, and record the scotoma limits as they are announced. Thus the permanent record is made simultaneously with the examination.

To assist in subsequent examinations, the prisms used and the size of test objects are noted on chart.

It is surprising how quickly and accurately this measurement can be made. A change of 1° may certainly be detected. The small scotomata of central and disseminate choroiditis can therefore be detected when easily overlooked by other methods.

The writer would not feel competent to treat a case of glaucoma without this wonderful instrument, which is, perhaps, the best demonstration of the value of the Stereoscope in Ophthalmology.

APPARATUS
for
DR. WELLS' SYSTEM OF FUSION TRAINING
may be obtained as follows:

PHORO-OPTOMETER, with Frame for holding Cards,
American Optical Company,
403 Washington Street, Boston, Mass.

WELLS STEREOSCOPIC CHARTS, 49 Black & White, 21 Colored,
E. B. Meyrowitz, Inc.,
520 Fifth Avenue, New York City.

STEREOSCOPES, with Clips for Extra Prisms,
SQUARE PRISMS, 38 mm., ground edge, —5^{Δ}, 10^{Δ} and 15^{Δ},
HEAD BANDS AND BARS, for Controlled Reading,
Pinkham & Smith Company,
292 Boylston Street, Boston, Mass.

STEREOGRAPHS, OR STEREOSCOPIC PICTURES,
Keystone View Company,
Meadville, Pa.

28.F.179.
The stereoscope in ophthalmolog1926
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